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Classifying and Mapping Native Grasslands of South Dakota's Northern Prairie Coteau and Characterizing Habitat for Dakota Skipper Conservation

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CLASSIFYING AND MAPPING NATIVE GRASSLANDS OF SOUTH DAKOTA'S NORTHERN PRAIRIE COTEAU AND CHARACTERIZING HABITAT FOR DAKOTA SKIPPER CONSERVATION

BY

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This thesis is approved as a creditable and independent investigation by a candidate for the Master of Science in Biological Sciences and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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ABSTRACT

CLASSIFYING AND MAPPING NATIVE GRASSLANDS OF SOUTH DAKOTA'S NORTHERN PRAIRIE COTEAU AND CHARACTERIZING HABITAT FOR DAKOTA SKIPPER CONSERVATION

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Native tallgrass prairie is becoming increasingly rare due to conversion and degradation, putting pressure on endemic prairie species such as the federally threatened Dakota skipper butterfly (*Hesperia dacotae*). To develop a conservation plan for the butterfly in South Dakota, accurate vegetation classification, mapping, and characterization are critical. The objectives of this study were to 1) rank prairie condition, 2) classify and map upland prairie, 3) characterize and compare vegetation at Dakota skipper inhabited and formerly inhabited sites, and 4) identify potential Dakota skipper habitat within a 225 mi^2 (58,275 hectares) study area of the SD Prairie Coteau. Condition metrics were developed following the NatureServe and Minnesota County Biological Survey (MCBS) guidelines. Sixty-seven relevé plots were sampled in upland prairie using the MCBS relevé sampling protocol and classified using multivariate analysis. Characterization of habitat was conducted using 50-m transects subjectively placed at 8 inhabited sites and 4 formerly inhabited sites. Cover by species using modified Daubenmire classes was estimated in six 1-m^2 quadrats placed every 10 m on alternate sides of transects. During butterfly flight time, flowering stems were counted along transects in a two-meter belt. Vegetation composition between inhabited and formerly inhabited sites was compared using multivariate analysis and Mann-Whitney U tests. A two-dimensional NMS solution of the phytosociological data found that axis one represented a moisture gradient (r = .55), while management regime influenced axis two (r = .22). Three plant communities, Upland Dry Prairie, Dry-Mesic Prairie and Mesic Prairie, were revealed using flexible beta (β = -.025) and Sørenson distance, and were mapped according to associated USDA ecological sites. The results of the vegetation comparison at inhabited and formerly inhabited sites showed no clear pattern, indicating that other factors like management history and critical minimum size may play a role in population extirpation. Potential habitat was identified by intersecting USDA ecological sites where Dakota skippers have been located with an untilled grassland layer in ArcGIS. The classification and mapping of upland communities and the potential habitat layer will provide a guide to future Dakota skipper surveys and aid in developing a recovery plan at the landscape scale.

CHAPTER 1

DELINEATION, RANKING, CLASSIFICATION AND MAPPING OF DAKOTA SKIPPER HABITAT ON A PORTION OF THE SOUTH DAKOTA PRAIRIE COTEAU

INTRODUCTION

Dakota Skipper (*Hesperia dacotae*) Biological Characteristics

The Dakota skipper butterfly (*Hesperia dacotae* (Skinner 1911)) is in the family Hesperiidae, distinguished from other butterflies by a thick, strong thorax and comparatively short wings that enable them to fly in powerful bursts or “skips” (Layberry et al. 1998). The Dakota skipper is a small to medium-sized skipper with adult wingspans ranging from 2.4-3.2 cm (Royer and Marrone 1992) and maximum larval size ranging from 19-22 mm long (McCabe 1981).

The Dakota skipper is a univoltine species of butterfly, completing one generation per year. Females lay eggs close to the ground on grasses and broad-leaved forbs during late June to early August (Layberry et al. 1998). Depending on temperature, eggs hatch after 8-20 days of being laid, and larvae build shelters at or below the soil surface at bases of bunchgrasses by weaving only stems or stems and litter fragments together (McCabe 1981, Dana 1991) (Figure 1.1).

Young larvae feed from inside their shelters, cutting off blades of grass and pulling them into the shelters as they eat them (Dana 1991), while mature larvae forage near their shelters at night (McCabe 1981, Dana 1991). Little bluestem (*Schizachyrium scoparium*) has been noted as a favored larval food plant (Royer and Marrone 1992), but larvae also feed upon other C4 grasses, including big bluestem (*Andropogon gerardii*) in its immature stages, prairie dropseed (*Sporobolus heterolepis*) and sideoats grama

(*Bouteloua curtipendula*) (Dana 1991). They have been noted to use some C_3 graminoids to a lesser extent, including Wilcox dichanthelium (*Dichanthelium wilcoxianum*), Kentucky bluegrass (*Poa pratensis*) and sun sedge (*Carex inops* subsp. *heliophila*) (Dana 1991).

The shelter-building behavior of larvae limits this species to habitats where shorter, thin-stemmed bunchgrasses are frequent (Dana 1991). Larger grasses such as big bluestem and Indiangrass (*Sorghastrum nutans*) have wider blades that would make cutting and harvesting difficult, and larvae would have to travel longer distances up stems to reach palatable parts of the plant (Dana 1991). Pastures dominated by smooth brome (*Bromus inermis*) would also not be ideal for Dakota skipper larvae because the widely spaced stems make it unsuitable for shelter building (Dana 1991).

The larval stage consists of six or seven instars. Diapause occurs during the fourth or fifth instar (McCabe 1981, Dana 1991, Royer and Marrone 1992). During late September, larvae move their shelters below the soil surface to overwinter (Dana 1991). After diapause larvae build shelters on the soil surface during April and May, where they stay another 29 to 40 days before pupating (Dana 1991) (Figure 1.1).

It has been hypothesized that temperature, local humidity and pH may be important factors influencing the success of Dakota skipper larvae (McCabe 1981, Dana 1991, Royer et al. 2008). Decreased humidity in the soil layer could render the larvae susceptible to dessication during hot summer months (Royer et al. 2008). Royer et al. (2008) measured local climate at larval nest zones at Dakota skipper sites in South Dakota, Minnesota and North Dakota and found that season-long mean larval nest zone temperature ranged from 17.8°C - 20.5°C, season-long mean larval nest zone dew point ranged from 13.9°C -16.8°C and average larval nest zone relative humidity ranged from 78.8% to 82.6%.

The pupal stage lasts for 13-19 days before adult butterflies emerge from pupae over a three-week period in June and July (McCabe 1981, Dana 1991) (Figure 1.1). The exact timing of emergence depends upon specific climatic conditions (McCabe 1981). The emergence of Dakota skipper adults often happens when the flowers of the important nectar source, purple coneflower (*Echinacea angustifolia*), flower (Royer and Marrone 1992). Males hatch about five days before females (Dana 1991). Adult butterflies live an average of three weeks (Dana 1991). They begin breeding immediately after emergence, and females lay eggs continually throughout their lifespan (McCabe 1981). During adult flight time, nectar flowers provide both food and water for Dakota skippers (Dana 1991). Reduced access to nectar sources could reduce adult survival and female fecundity (Dana 1991).

Dakota skippers are moderately opportunitistic in their choices of nectar flowers, but do show clear preference for certain species (Dana 1991). Nectar sources vary slightly by region. In North Dakota important nectar sources have been noted as prairie coneflower (*Ratibida columnifera*), daisy fleabane (*Erigeron strigosus*) purple coneflower, blanket flower (*Gaillardia aristata*), black-eyed Susan (*Rudbeckia hirta*), harebell (*Campanula rotundifolia*) and plains yellow primrose (*Calylophus serrulatus*) (McCabe 1981, Royer and Marrone 1992). In Minnesota common nectar sources are described as purple coneflower, standing milkvetch (*Astragalus adsurgens*), purple locoweed (*Oxytropis lambertii*), woolly verbena (*Verbena stricta*), blanket flower

(*Gaillardia aristata*) and groundplum milkvetch (Dana 1991, Swengel and Swengel 1999).

Although adult activity has been noted to shift slightly from year to year (McCabe 1981), Dakota skippers are not inclined to dispersal (Royer and Marrone 1992). McCabe (1981) observed captured Dakota skippers to fly 150-200 feet when released, before returning slowly back to the place where they were originally disturbed. Observations in the field have shown average adult movements of less than 300 m in 3-7 days (Dana 1991). During their short adult lifespan, Dakota skippers are believed to travel not more than 1.6 km (one mile) from their emergence location (Licht 1997).

Habitat Types

Dakota skippers are restricted to high quality native prairie composed of a diverse mixture of native forbs and grasses (Cochrane and Delphey 2002, Dana 1997). Royer and Marrone (1992) identified two major habitat types where Dakota skippers occur and labeled them Type A and Type B habitats (the 'A' does not imply superior habitat type to 'B'). Type A habitat is described as wet-mesic tallgrass prairie, with topographically flat to low relief, dominated by bluestem grasses (big bluestem, little bluestem) (Royer and Marrone 1992). Three indicator species of this habitat are wood lily (*Lilium philadelphicum*), harebell and white camas (*Zigadenus elegans*). This wet-mesic habitat typeis found in the Dakota skipper's eastern North Dakota range (Royer and Marrone 1992) and southern Manitoba range (Rigney 2013). In Manitoba the Dakota skipper was found in drier areas of the wet-mesic habitat type, located on rises and areas with slightly higher elevation, dominated by big bluestem, little bluestem and prairie dropseed (Rigney 2013). Within this habitat type, black-eyed Susan was noted as the most commonly used nectar source in Manitoba (Rigney 2013) and McCabe (1981) reported nectar source preference as follows: prairie coneflower, daisy fleabane, purple coneflower, blanket flower, black-eyed Susan, harebell, and plains yellow primrose in North Dakota.

Type B habitat is described as dry-mesic prairie with more pronounced relief than Type A, dominated by bluestems (*Andropogon gerardii, Schizachyrium scoparium*) and needle grasses (*Hesperostipa* spp.) (Royer and Marrone 1992, Royer et al. 2008). This habitat occurs on the Missouri Coteau in North Dakota and the Prairie Coteau in South Dakota (Royer and Marrone 1992). Dana (1997) described Dakota skipper habitat in western Minnesota as dry-mesic prairies dominated by the midheight grasses little bluestem, prairie dropseed and porcupine grass (*Hesperostipa spartea*) with a diverse mixture of forbs including pasque flower (*Pulsatilla patens*), prairie blue-eyed grass (*Sisyrinchium campestre*), hoary puccoon (*Lithospermum canescens*), purple prairie clover (*Dalea purpurea*), standing milkvetch, prairie groundsel (*Packera plattensis*), prairie goldenrod (*Oligoneuron album*), purple coneflower, goldenrods (*Solidago* spp.), gayfeather species (*Liatris* spp.) and asters (*Symphyotrichum* spp.) (Dana 1997). Purple coneflower is noted as an important nectar source in this habitat (Dana 1991, Skadsen 1997, Swengel and Swengel 1999).

In northeastern South Dakota the two types of habitat meet and can occur in close proximity to each other (Royer and Marrone 1992). Skadsen (1997) notes that Dakota skippers occupy the drier portions of Little Bluestem-Porcupine Grass Dry-Mesic Hill Prairie and Northern Mesic Tallgrass Prairie plant communities on the South Dakota Prairie Coteau. The common grasses at all Dakota skipper sites were big bluestem, little bluestem and porcupine grass (Skadsen 1997).

Dakota Skipper Historical and Current Distribution

The Dakota skipper was listed as a federally threatened species on October 23, 2014 by the U.S. Fish and Wildlife Service (Parham et al. 2014). The Dakota skipper is suspected to have originally occurred in mixed grass and tallgrass prairies of northern Illinois, Iowa, South Dakota, Minnesota, North Dakota, southern Manitoba and southeast Saskatchewan, although the exact historic distribution may never be known due to the amount of prairie already converted to cropland or developed before extensive biological surveys were done (McCabe 1981, Cochrane and Delphey 2002).

Currently, the Dakota skipper is relegated to high-quality native prairie remnants in Minnesota, North Dakota, South Dakota, Saskatchewan and Manitoba (Figure 1.2) (Britten and Glasford 2002, Federal Register 2013). The core distribution occurs in northeastern South Dakota, western Minnesota and the northeastern half of North Dakota (Royer and Marrone 1992) (Table 1.1). It is considered extirpated from Illinois and Iowa. The species was last recorded in 1888 in Illinois, identified post-humously from a museum specimen, and 1992 in Iowa (Orwig and Schlict 1999). Royer and Marrone (1992) acknowledge there is a possibility of finding the Dakota skipper in eastern Montana in habitat similar to that of Dakota skipper sites in western North Dakota. McCabe (1981) noted an association between Dakota skipper occurrences and the alkaline prairies on the shorelines of ancient glacial lakes in east-central and southern North Dakota, northeastern South Dakota, and the one occurrence in northern Illinois, although there are sites in the southern portion of its range that are not near any glacial lakes. Throughout this broad range, Dakota skipper populations only occur in areas of native midgrass to tallgrass prairies with sufficient larval food plant abundance and nectar sources (Royer and Marrone 1992).

Of the 85 historic Dakota skipper collection sites located in South Dakota, the U.S. Fish and Wildlife Service considers the Dakota skipper present or persistent at 14 and extirpated or possibly so from 25, leaving 46 sites with unknown status (Federal Register 2013). Most of historic and currently occupied sites in South Dakota are located on the South Dakota Prairie Coteau (Federal Register 2013), an area that still retains a relatively large amount of grassland due to steep topography and rocky glacial till (Smart et al. 2003).

Reasons for Decline

Much of the tallgrass and mixed grass prairie that existed within the historical range of the Dakota skipper has been converted to agricultural land due to the highly productive nature of prairie soils (Samson et al. 2004). Estimates of the amount of remaining prairie vary. Samson et al. (2004) estimated 13% of the tallgrass prairie’s historic extent and 29% of the mixed grass prairie’s historic extent remains in the Great Plains. White et al. (2000) estimated 13% of the tallgrass prairie ecoregion is left uncultivated in North America. The native prairie that remains is highly fragmented (White et al. 2000), and the fragments are threatened by degradation from invasive species and disappearance due to succession to woody species (Koper et al. 2010, DeKeyser et al. 2013).

Both the wet-mesic and dry-mesic habitat types of the Dakota skipper often occur on marginal agricultural land, which has most likely saved many populations from conversion to agriculture (McCabe 1981, Royer and Marrone 1992). However, Royer and

Marrone (1992) and Skadsen (1997) noted sites in North Dakota and South Dakota that were lost to agricultural conversion as recently as 1992, and Royer and Marrone (1992) listed destruction of habitat for agriculture purposes as an “existing threat” to Dakota skipper survival.

Degradation of habitat quality is another threat to Dakota skipper populations (Royer and Marrone 1992). Dakota skippers have not been observed in degraded prairie (Swengel and Swengel 1999). Lack of native nectar species, native bunchgrasses and altered soil structure in degraded prairies could all be detrimental to Dakota skipper populations (Dana 1991, Dana 1997). Degradation of habitat can happen through improper management, such as overgrazing (Dana 1997), indiscriminate herbicide spraying, which can reduce the amount of native forbs (Royer and Marrone 1992) or no management, which leads to invasion by woody shrubs (McCabe 1981).

Management that promotes native species, such as grazing, prescribed burning and haying, must be carefully implemented at Dakota skipper sites. Although, Dakota skippers occur in prairies that are grazed by cattle (Skadsen 1997, Dana 1997), population numbers reduce as grazing intensity increases (Dana 1997), and McCabe (1981) recorded that prairies in North Dakota became less suitable for the Dakota skipper after even moderate grazing. Heavy grazing could negatively affect Dakota skipper populations by reducing nectar sources (Dana 1997) or changing soil structure through repeated compaction by hooves, altering soil moisture and local humidity in the larval nesting zone region, thus rendering larvae susceptible to desiccation in the late summer months (Royer et al. 2008).

Prescribed burning, commonly implemented to help maintain cover of native species, has coincided with declines in the Dakota skipper and other prairie specialist butterflies (Dana 1991, Swengel 1996). Prescribed burning puts Dakota skipper eggs and larvae at risk to fire-caused mortality (Dana 1991). Fire is part of the historical prairie disturbance regime, and it is likely this species contended with fire in the past by recolonizing habitat after burns (McCabe 1981). However, the fragmented status of the prairie ecosystem and the distance between known Dakota skipper populations makes recolonization unlikely (McCabe 1981, Royer and Marrone 1992).

Haying can be detrimental or beneficial to Dakota skipper populations depending on the timing of the haying. Managers that hay native prairie in the Great Plains have the option of doing it two different times during the year, either before the needle-like seeds of the needle grasses develop in early summer or during the latter part of the season after the seeds fall (McCabe 1981). Haying done during early to mid-summer removes nectar sources, which would force adult Dakota skippers to search for nectar elsewhere (McCabe 1981). The most successful management to maintain Dakota skipper populations has been late summer or fall haying, a practice that maintains native vegetation, leaves nectar sources during Dakota skipper flight time, and causes no direct mortality to the butterfly (McCabe 1981, Dana 1991, Swengel and Swengel 1999).

The fragmentation of the prairie has led to the isolation of Dakota skipper populations on high-quality native prairie remnants separated by a matrix of cropland and degraded pastureland. In addition to inhibiting recolonization (McCabe 1981, Royer and Marrone 1992), reduced connectivity between habitat patches has caused isolation-by-distance in Dakota skipper populations (Britten and Glasford 2002), meaning there is a negative correlation between the spatial distances between populations and their genetic similarity (Slatkin 1993). Isolation causes genetic drift in populations (Britten and Glasford 2002) decreasing genetic variability and species fitness over time (Frankel and Soulé 1981).

Grassland Inventory

The potential isolation of Dakota skipper populations makes the management of existing prairie remnants inhabited by Dakota skippers vital to preserving those populations (Cochrane and Delphey 2002). Therefore the identification, securing and enhancing of existing habitat is necessary for its recovery. Due to the relatively high amount of native grassland remaining on the South Dakota Prairie Coteau, northeastern South Dakota has been identified as one of the strongholds for Dakota skippers (Royer and Marrone 1992). Private landowners own a large amount of the grassland on the Prairie Coteau (Bauman et al. 2014). Limited access to private grasslands by natural resource managers makes vegetation condition and habitat suitability difficult to assess.

South Dakota grasslands have been studied and inventoried to varying degrees over the years. In 1977, Rodney Baumberger published an inventory of land in the entire state, estimating that 53% of land was used as rangeland, and 42% of rangeland was in excellent and good condition in eastern South Dakota, according to guidelines of the SCS National Range Handbook (USDA 1976) (Baumberger 1977). Jeremy Higgins (1999) conducted a study comparing the floristic quality of paired public and private native grassland sites across eastern South Dakota. He found a loss in species biodiversity and floristic quality on many of the public and private sites compared to reference well-managed tallgrass prairie relicts. State Game Production Areas in eastern South Dakota were inventoried in 2007 and 2008 and summarized by Dave Ode (2009). The plant communities were characterized and given a quality ranking from 1-5 based upon the proportion of exotic species to native species. A ranking of 1 signified that cover was completely dominated by exotics growing on non-native sod, and a ranking of 5 signifyied that cover was dominated by a high diversity of native species and few exotics. No sites in Day and Roberts counties were ranked as 5, the best quality ranking. Out of the 43 total sites sampled, one site was ranked 4 (native species and forbs common with some exotics) and five sites were ranked 3 (native species present but cover dominated by exotics). The remaining sites were ranked 1 and 2 (dominated by exotics and requiring long-term management or cultivation to recover native vegetation) (Ode 2009).

The most thorough inventory of native tallgrass prairie on the Prairie Coteau was completed in 1995-1996 by Mark Leoschke, who inventoried select natural areas within Roberts, Marshall and Day counties. Leoschke's sites were chosen for their size (at least 1036 ha (4-m^2)) and percent of native vegetation (at least 78%). The condition was measured using the Minnesota Natural Heritage Program guidelines, which designates condition by using the letters A – D, A representing an undisturbed plant community and D representing a severely disturbed community. The letter E was used to designate a plant community that could not be ranked because of lack of information. The level of disturbance was determined by the diversity of the species assemblage, the proportion of exotic species to native species, the condition of the topsoil layer and soil structure and the presence of certain species that indicated little to no disturbance. These general guidelines were expanded upon and tailored for each plant community type. Leoschke ranked each quarter section and then averaged across each site for each plant community.

The number of acres of each plant community within each site was determined by associating mesic prairie with soils of 1-9% slope and dry-mesic prairie with soils with slopes greater than 9%. The plant community classifications were developed by The Nature Conservancy and included three upland prairie groups: Little bluestem- Porcupine Grass Dry –Mesic Hill Prairie, Northern Mesic Tallgrass Prairie, and Northern Wet-Mesic Tallgrass Prairie. The report included maps showing the boundaries of each natural area and written descriptions of the location of each plant community within each surveyed natural area (Leoschke 1997).

To create a baseline inventory of potentially high quality grasslands, Bauman et al. (2014) manually digitized grasslands from Farm Service Agency's (FSA) aerial imagery to produce an ArcGIS layer of untilled grasslands on the South Dakota Prairie Coteau. The approach was unique because it utilized the 2012 FSA Common Land Unit (CLU) layer, a cumulative record of all land that had been enrolled in a government crop program since the 1950's. This layer was used to distinguish and exclude grasslands that had tillage history, but had since revegetated to grass. This report found 1,065,262 acres (431,096.2 ha) of grasslands with no tillage history on the South Dakota Prairie Coteau. It is important to note that grasslands with no tillage history can still be degraded from poor management, shrub encroachment and exotic species invasion (DeKeyser et al. 2013). However, many of the tilled lands that were put back into grassland through the Conservation Reserve Program, which used smooth brome as a primary component of many seed mixtures (DeKeyser et al. 2013). Conversion of grassland to cropland continues, thus reducing habitat critical for wildlife species (Faber et al. 2012). The Upper Midwest and the Great Plains are undergoing the highest rate of net change through grassland conversion to cropland (Wright and Wimberly 2013), making the need to inventory and conserve remaining habitat urgent for prairie endemic species such as the Dakota skipper.

Objectives

A continuous assessment of the quality of grasslands, their spatial extent and locations provides important information to decision-makers when designing conservation strategies (Gauthier and Wiken 2003). An up-to-date comprehensive inventory of classified, mapped and ranked plant communities of the South Dakota Prairie Coteau is needed to address the issue of Dakota skipper population maintenance and recovery. A successful targeted conservation plan for the Dakota skipper requires knowledge of the amount, location and condition of suitable habitat.

The objectives of this project thus included identifying, mapping, and characterizing upland prairie plant communities on the South Dakota Prairie Coteau. First, grassland was delineated and the condition of existing prairie was assessed. Second, upland prairie communities were classified and mapped. Third, vegetation composition at sites inhabited by the Dakota skipper and sites where the Dakota skipper is considered extirpated was characterized and compared. Fourth, potential Dakota skipper habitat was predicted using information gathered from sites where Dakota skippers currently exist. Due to the magnitude of labor necessary in achieving the objectives, the project focused on only a portion of the South Dakota Prairie Coteau chosen for its high number of Dakota skipper occurrences.

Secondary objectives from the work included a quantitative way to measure condition in upland tallgrass prairie, a quantitative classification of upland prairie on the

South Dakota Prairie Coteau, which further refines existing prairie classifications, maps with locations of important prairie patches, and a map of potential Dakota skipper habitat. This project will not only benefit the Dakota skipper, but also other endemic prairie-dependent species by standardizing assessment procedures for future grassland classification and inventory efforts in the region.

STUDY AREA

The study area encompassed 58,275 hectares (24-km X 24-km) of the northern South Dakota Prairie Coteau (Figure 1.3). The southeast corner of the study area is located where 459th Ave intersects with State Highway 12, approximately 1.6 km (one mile) east of Summit, SD at 45°18'42.97" N and 97° 1'13.35" W. The coordinates for the northwest corner are 45°31'46.11" N and 97°19'47.16" W. The Prairie Coteau is an iron-shaped plateau rising to 610 meters a.s.l., located between the Minnesota River and Red River lowlands and the James River Watershed. The underlying bedrock is primarily Pierre shale. Numerous glacial movements have deposited large amounts of till on top of the bedrock, creating an irregular surface with relief of up to 120 meters. The resulting landscape is undulating, characterized by rolling hills and swales (Hogan and Fouberg 2001, Flint 1955).

Soils of the Prairie Coteau are of the Vienna and Kranzburg series, developed from glacial till and loess material and classified as fertile chernozem soils (Derscheid and Westin1970). The major land use on the Coteau is row crop agriculture. Pasture and haylands remain where the rocky till and poor drainage have discouraged tillage, especially in the northern portion of the Coteau and along the escarpment where the topography is the most irregular and slopes are the steepest (Smart et al. 2003). Within pastures, vegetation was originally characteristic of tallgrass prairie with a mixture of cool season and warm season grasses (Weaver 1954). However, due to the alteration of historic disturbance regimes and fragmentation, many pastures in the northern Great Plains are now dominated by Kentucky bluegrass and smooth brome (DeKeyser et al. 2013). Additional habitats found on the Coteau include lakes, fens, other wetlands, and wooded coulees.

The Coteau has a humid continental climate characterized by hot summers and cold winters. Within the study area, the number of frost free days ranges from 110-140. Annual average precipitation is 51-56 cm, with 28-38 cm falling as rain during a growing season that ranges from mid-May to mid-September (Bryce et al. 1998, Hogan and Fouberg 2001).

Land ownership across the study area is divided between private landowners, the Sisseton-Wahpeton-Oyate tribe and Bureau of Indian Affairs (grazing land, hayed land, and fallow land), U.S. Fish and Wildlife Service (wildlife production areas and refuges), and South Dakota Department of Game Fish and Parks (game production areas and state parks).

METHODS

Delineation

A layer was created in ArcGIS of all grasslands within the study area. This layer did not distinguish between grasslands that were at one time cultivated. The layer was created manually in ArcGIS using the 2012 National Agriculture Imagery Program (NAIP) imagery as a guide. Roadside surveys were used to determine land use in cases where distinctions could not be made through aerial imagery alone. To verify the layer, fifty random points were created in ArcGIS and were verified using road-side surveys. Forty-nine out of the fifty points could be viewed from the road and confirmed as grassland. One point was out of reach of roads and located on private land. Permission was not sought and so the point was not verified with a roadside survey. Wetlands were included in the initial delineation. After the layer was complete, the National Wetlands Inventory (USFWS 2013) layer was clipped out of the grassland layer to remove designated wetlands from the grassland layer. Small wetland and riparian areas that were not mapped by the National Wetlands Inventory were included in the grasslands layer.

Condition Ranking

Condition metrics were developed to rank the condition of grasslands within the study area (Table 1.2). Rankings were based on the vegetation condition portion of the ecological integrity assessment framework of NatureServe (Unnasch et al. 2008). The condition metrics were tailored to the tallgrass prairie using MCBS condition guidelines for upland prairie in Minnesota (MNDNR 2014) and expert opinion. The metrics were assessed in the field for the first two weeks of sampling and adjusted to better represent the range of condition of grasslands within the study area.

The metrics used to rank condition were relative cover of native species, absolute cover of exotic species, cover of native increaser species and presence and abundance of native decreaser species (Table 1.2). Native increaser species are defined as those species that increase under grazing while a decreaser species is defined as a species that tends to decrease under grazing pressure (Voigt and Weaver 1951). Based on the above definition, MCBS condition guidelines (MNDNR 2014) and expert opinion in the field, a list of local increasers and decreasers was developed (Table 1.3 and Table 1.4).

To ensure uniform management history across individual prairie stands, boundaries were delineated by land ownership and further split into management units by fences. If condition was noticeably different within the same stand due to past management (e.g., farmland that was reclaimed as pasture land) or present management, then the stand was divided into different units and each unit was ranked individually. Stands were walked until rank could be assigned. If stands were recently grazed, this was noted on the condition ranking form. In large prairie remnants, hillsides and ridges where native species are usually more competitive were surveyed more intensely than areas dominated by invasive grasses.

A stand was assessed and given a rank for each metric individually that reflected the average rank for that metric across the stand (Table 1.2). The rank for each metric was then assigned a point value, A = 5, A- = 4.375, B = 3.75, B- = 3.125, C- = 2.5, C = 1.875 and D = 1.25. The point values were averaged together to get an overall rank for each prairie stand, A = 4.4-5, B = 3.1-4.3, C = 1.9-3.0 and D = <1.9. Stands having greater than 95% exotic plant cover were considered exotic grasslands and denoted as condition E and given a score of zero.

Classification and Mapping

Vegetation Sampling

We used the relevé sampling methodology of the Minnesota County Biological Survey (MCBS) (MNDNR 2007) to characterize the vegetation of native prairie tracts. Sixty-seven 10-m X 10-m relevés were sampled throughout July and August in 2014 and 2015. Relevé plots were subjectively placed in areas of relatively uniform physiognomy and floristic composition in upland prairie vegetation. Subjective placement was chosen due to the highly fragmented nature of the landscape and restrictions on time and resources (MNDNR 2007, Jennings et al. 2009). Within each plot, vegetation cover and height of each physiognomic class was recorded, woody plants, forbs and graminoids (MNDNR 2007). The cover by species within each physiognomic class was estimated using the Braun-Blanquet (1932) cover class scale. Species not detected in the plot but occurring within a 1-meter boundary of the plot were also noted on the relevé forms.

Abiotic variables were recorded for each relevé, including the continuous variables aspect (degrees), litter depth and type, slope (degrees), elevation (m), date of sampling, and the categorical variables, management regime (grazed, hayed, rested, burned), topographic position (crest, upper, middle, lower, toe, flat, depression), and condition. The condition of vegetation in each individual relevé plot was determined separately from each stand using the same criteria (Table 1.2). The soil map unit and ecological site where each plot occurred was determined later by overlaying the GPS locations of plots onto a USDA soil survey data layer in ArcGIS.

Data Preparation

A species main matrix was created by organizing the data into plot vs. species. A second matrix was created by plot vs environmental factors. In the species main matrix, prior to analysis, species cover class data were converted to cover class midpoints (Tüxen and Ellenberg 1937) and log transformed using a generalized log transformation to put more emphasis on less abundant species (McCune and Grace 2002). The species cover data was relativized by maximum species values to help equalize uncommon species with common species (McCune and Grace 2002). Species that occurred in less than 5% of plots were excluded from the analysis to reduce noise. A total of 67 plots and 126 species were used in the final analysis.

Gradient Analysis

Nonmetric Multidimensional Scaling (NMS) was performed using PC-Ord v. 6.12 (McCune and Medford 2011) to examine the relationship between species distribution and environmental gradients. NMS was run using Sørenson (Bray-Curtis) distance, with a maximum of 500 iterations, 600 runs with real data and 200 runs with randomized data. To determine the drivers of each axis, the correlation coefficients between species from the main matrix and continuous variables from the second matrix and each axis were examined. The resulting NMS plot configurations were overlaid with the categorical environmental variables from the secondary matrix for further examination of underlying ecological and environmental gradients.

Cluster Analysis

The space conserving cluster methods of group average, Ward's method, and flexible beta (β = -.025), using both Sørenson (Bray-Curtis) and Euclidean distance where appropriate, were applied to the data (McCune and Grace 2002). To determine an acceptable classification, groupings from all hierarchical clustering methods were evaluated after each successive dendrogram split by overlaying the clusters on top of the NMS ordination to ensure that groups did not overlap, and that groups divided along meaningful environmental gradients (Lötter et al. 2013). Additionally, the clusters were examined using internal evaluators that evaluate properties of the clusters themselves and external evaluators that compare the clusters to previously established standards or external criteria (Gauch and Whittaker 1981, Lötter et al. 2013).

To create an acceptable and interpretable classification, clusters should be internally homogeneous and contain numerous faithful species (Lötter et al. 2013). Multi-response permutation procedures (MRPP) were performed to evaluate the level of homogeneity within groups (McCune and Grace 2002). Indicator species analysis was performed upon the final groups using the Dufrêne and Legendre (1997) method (McCune and Grace 2002). The average p-value of all indicator species for each group, and the total number of significant indicator species ($p < 0.01$) were tallied to measure the degree of faithful species at each grouping level (McCune and Grace 2002).

As an external evaluator, final group determinations were compared to existing classifications, the TNC classification cited in Leoschke (1997), the Upland Prairie System in Minnesota developed through the Minnesota Biological County Surveys (MNDNR 2005) and the Great Plains temperate grassland associations of the US National Vegetation Classification (USNVC 2015). The classification in the Leoschke (1997) report was given the most weight in the final decision because it described many of the same grasslands.

Mapping

While it is more common to map vegetation communities using remotely sensed imagery, methods using alternative data sources are also acceptable (TNC 1998). Due to time and resource limitations and inability to distinguish fine floristic differences in grassland vegetation through aerial imagery, plant communities were mapped in ArcGIS using USDA ecological site units. NRCS defines ecological sites as units of land that have similar soil properties, hydrology and vegetation. NRCS maps ecological sites using the NRCS soil survey (Butler et al. 2003). The ecological site layer was intersected with the delineated grasslands layer to include only existing grasslands in the mapping procedure.

RESULTS

Delineation and Condition Ranking

The grasslands layer encompassed 34,368.39 ha of the study area (Figure 1.4). Due to the recently accelerated rate of conversion in this area, it is very possible that the grassland layer was out of date as it was created from 2011 imagery. Approximately 7610 ha were surveyed of which 430 ha, 1920 ha, 3050 ha, 2020 ha and 190 ha were ranked A, B, C, D and E, respectively (Figure 1.4).

During the first year of condition ranking, a new Dakota skipper site was found. The site had not previously been surveyed before because it was not visible from the road. The site was located on a tribally owned hay prairie.

Classification

Gradient Analysis

A 2-dimensional NMS solution was chosen for the interpretation of the phytosociological data (minimum stress = 20.8) with axis one explaining 55% and axis two explaining 22% of the variation (77% cumulative) (Figure 1.5).

Examination of the main matrix species correlation coefficients with the ordination axes (Table 1.5) showed that axis one was highly associated with a moisture gradient. The five species with the highest positive correlation coefficients for axis 1 were species that prefer xeric prairie environments: needleandthread (*Hesperostipa comata*) (r = 0.62), blanket flower (r = 0.59), Richardson’s alumroot (*Heuchera* *richardsonii*) (r = 0.58), golden aster (r = 0.57) and fringed sage (*Artemisia frigida*) (r = 0.56). Species preferring more mesic environments had the highest negative correlation coefficients with axis one, including heartleaf alexanders (*Zizia aptera*) (r = -0.72), timothy (*Phleum pratense*) (r = -0.73), veiny meadowrue (*Thalictrum venulosum*) (r = -0.62), golden alexanders (*Zizia aurea*) (r = -0.55) and gayfeather species (*Liatris* spp.) (r = -0.54), which included rough (*L. aspera*) and Rocky Mountain gayfeather (*L. ligulistylis*).

The USDA ecological site overlay onto the ordination configuration confirmed the moisture gradient. Subirrigated and limy subirrigated ecological sites that are characterized by well drained soils (Bachman 1997, Miller et al. 1977) clustered on the negative end of the axis. Shallow gravel and very shallow ecological sites characterized by well drained to excessively drained soils, leading a more xeric environment (Bachman 1997, Miller et al. 1977), clustered on the positive end of the axis (Figure 1.6).

The overlay of the management regime of each plot on the NMS configuration showed a pattern associated with axis 2 (Figure 1.5). Hayed plots clustered towards the top of axis 2, grazed plots clustered in the middle and rested plots clustered at the bottom of the ordination configuration. Three of the top five species with the highest positive correlation coefficients with axis 2, false dandelion (r = 0.48), breadroot scurfpea (r = 0.40), and groundplum milkvetch (r = 0.41) are decreaser forbs (Table 1.4), i.e., the first to disappear under grazing. Decreaser forbs would be expected to be more frequent in hayed or rested plots. Two of the three most negatively correlated species with axis 2, Canada goldenrod (r = -0.73) and cudweed sagewort (*Artemisia ludoviciana*) (r = -0.664) are increaser forbs (Table 2.2).

The continuous environmental variables elevation, slope and physiognomic cover classes showed no correlation with either axis and did not shed light on plant community patterns (Table 1.6).

Cluster Analysis

The overlay of cluster groups on the NMS ordination configuration showed fairly clear separation between groups along the moisture gradient for the two, three and four group clusters found by the group average method, the two group and three group cluster found by flexible beta ($\beta = -.025$) method and the two group cluster found by Ward's method (Figure 1.7). Group average and flexible beta ($\beta = -.025$) methods produced the same clusters at the two group level.

Of the five cluster options that showed clear separation when overlaid on the NMS ordination (Figure 1.7), the three group cluster produced by flexible beta ($\beta = -.025$) had the highest MRPP chance-corrected within-group agreement value (A) of 0.314 (Table 1.7). The two groups produced by flexible beta ($\beta = -.025$) and group average had the highest average p-value of 0.3654 resulting from the indicator species analysis, and the three group cluster produced by group average had the highest number of significant indicator species (Table 1.7). The four group cluster produced by the group average method contained one group consisting of one plot, which made further MRPP and indicator species analysis impossible for that cluster.

Given the conflicting results from the internal evaluators, the final plant communities were determined by comparing each group of clusters to existing classifications. The TNC classification used by Leoschke (1997) described three prairie plant communities on the South Dakota Prairie Coteau: Little bluestem- Porcupine Grass

Dry –Mesic Hill Prairie, Northern Mesic Tallgrass Prairie, and Northern Wet-Mesic Tallgrass Prairie. After examination of the floristic summaries of the 3 group clusters created by each method, it was determined that the groups produced by group average and flexible beta (β = -.025) were most similar to the three communities described by Leoschke (1997). There was a difference of only five plots between the 3 group clusters produced by group average and flexible beta (β = -.025) (Figure 1.7). The 3 group cluster produced by flexible beta (β = -.025) was chosen for the final classification because it has been noted as a preferred cluster method (Aho et al. 2008, Tichý et al. 2009, Löetter et al. 2013).

Plant Community Descriptions

Pruning the dendrogram produced by the flexible beta (β = -.025) cluster method using Sørenson distance at three plant communities left 8.7% of the information remaining (Figure 1.8). The three prairie plant communities were named Upland Dry Prairie dominated by little bluestem – porcupine grass, Dry-Mesic Prairie dominated by porcupine grass – little bluestem – big bluestem and Mesic Prairie dominated by big bluestem. The three groups divided along the soil moisture gradient when overlaid on the NMS ordination of relevé plots with only slight overlap occurring between the Upland Dry Prairie and Dry-Mesic Prairie (Figure 1.9). MRPP using Sørenson distance applied to the three groups produced an A value of 0.3149, indicating homogeneity within groups is more than expected by chance, and a p-value for delta below 0.05.

Upland Dry Prairie (*Schizachyrium scoparium – Hesperostipa spartea)*

This community occurred on well drained to excessively drained soils of outwash plains. This community aligned with very shallow and shallow gravel ecological range sites

(Table 1.8) named for the underlying soil material of calcareous very gravelly sand (Bachman 1997, Miller et al. 1977). Graminoid cover ranged between interrupted to continuous (50-100%). Little bluestem and porcupine grass were the dominant species for this type (Table 1.9). Subdominant grasses included prairie dropseed, green needle grass and needleandthread (Table 1.9). Forb and shrub cover ranged between absent to sparse (0-25%). Forbs that contributed the most to cover included purple coneflower, stiff sunflower and northern bedstraw. Forbs with high constancy that contributed less to cover included purple prairie clover, prairie turnip (*Pediomelum esculentum*), bastard toadflax (*Comandra umbellata*), Richardson's alumroot, dotted gayfeather (*Liatris punctata*), heath aster (*Symphyotrichum ericoides*), common yarrow (*Achillea millefolium*), groundplum milkvetch and Flodman's thistle (*Cirsium flodmanii*). Indicator species that rarely occurred in the other two community types included golden aster, Richardson's alumroot, standing milkvetch, blanket flower, Pennsylvanica cinquefoil (*Potentilla pensylvanica*) and scarlet gaura (*Gaura coccinea*) (Table 1.10). A full species list with abundance and constancy of values for Upland Dry Prairie can be found in Appendix A.

Dry-Mesic Prairie (*Hesperostipa spartea – Schizachyrium scoparium – Andropogon gerardii*)

This community occurred mainly on well drained soils formed in glacial till and silty material over loamy glacial till. This community aligned with loamy to thin loamy ecological range sites (Table 1.8) named from the underlying calcareous clay loam material (Bachman 1997, Miller et al. 1977). Graminoid cover ranged between interrupted to continuous (50-100%). Porcupine grass, little bluestem and big bluestem were dominant grasses (Table 1.11). Subdominant grasses included sideoats grama and prairie dropseed (Table 1.11). Forb and shrub cover ranged between barely present to patchy (1-50%). Forbs accounting for the most cover were northern bedstraw, stiff sunflower and Canada goldenrod (Table 1.11*)*. Forbs with high constancy values that contributed less to cover included Flodman's thistle, prairie violet (*Viola pedatifida*), candle anemone (*Anemone cylindrica*), silky aster (*Symphyotrichum sericeum*) and Virginia groundcherry (*Physalis virginiana*). Leadplant (*Amorpha canescens*), a shrub, contributed to more cover than any forb on average (Table 1.11). There were no indicator species exclusive to this group (Table 1.10). A full species list with abundance and constancy values for Dry-Mesic Prairie can be found in Appendix A.

Mesic Prairie (*Andropogon gerardii*)

All Mesic Prairie plots occurred in topographically level areas in moderately well drained to poorly drained calcareous loam and silt-loam soils that were formed from glacial till, glacial outwash or alluvium. This community aligned with subirrigated and limy subirrigated ecological sites (Table 1.8). Graminoid cover ranged between interrupted to continuous (50-100%). Big bluestem was the dominant species (Table 1.12). Subdominant grasses included Indiangrass, porcupine grass, switch grass (*Panicum virgatum*), and cord grass (*Spartina pectinata*) (Table 1.12). Forb cover ranged between sparse and patchy (5-25%) with veiny meadowrue accounting for the most cover (Table 1.12). Other constant forbs that contributed less to cover included Flodman's thistle, northern bedstraw, gayfeather spp. (*L. aspera* and *L. ligulistylis*) and white camas (*Zigadenus elegans*). Shrub cover was absent (0 - <1%). Species indicative of Mesic Prairie that were not found commonly in the other communities included snakeroot

(*Prenanthes racemosa*), golden alexanders (*Zizia aurea*), wood betony (*Pedicularis canadensis*) and black-eyed Susan (Table 1.10). A full species list with abundance and constancy values for the Mesic Prairie can be found in Appendix A.

Mapping

Plant communities were mapped according to their associated ecological sites: Upland Dry Prairie by shallow gravel and very shallow sites, Dry-Mesic by loamy and thin loamy sites, and Mesic Prairie by subirrigated and limy subirrigated sites (Table 1.8). On the final map Upland Dry Prairie, Dry-Mesic Prairie and Mesic Prairie covered 13,537.93 ha, 31,049.06 ha and 3,167.98 ha respectively (Figure 1.10). Accuracy of these figures is dependent on precision and accuracy of the soil surveys. Fine distinctions in topography or soil may be overlooked in classifying soils at a landscape scale. The accuracy of this map remains to be verified in the field.

DISCUSSION

NMS analysis determined two important factors influencing species composition. A moisture gradient, as determined by local topography and soil type, was the primary driver of the ordination. The gradient analysis identified management regime as a secondary influence on species composition. The different types of management, i.e., haying, grazing, burning and idle, mimic the historical disturbance regime of the tallgrass prairie (Collins 1987). The management influence on plant community composition reflects the potential variation found in grassland communities in response to different disturbances (Collins 1987).

The three prairie plant communities identified in this study coincided closely with those described by Leoschke (1997). The Little Bluestem- Porcupine Grass Dry –Mesic

Hill Prairie, Northern Mesic Tallgrass Prairie and Northern Wet-Mesic Tallgrass Prairie plant communities recognized in Leoschke's study shared similar soil characteristics, dominant grasses and diagnostic forbs with Upland Dry Prairie, Dry-Mesic Prairie and Mesic Prairie types, respectively. A minor difference existed between Dry-Mesic Prairie and the similar Northern Mesic Tallgrass Prairie. The cover of the Dry-Mesic Prairie community was dominated mostly by the midheight grasses, porcupine grass and little bluestem rather than tallgrasses. In the description of Northern Mesic Tallgrass Prairie, tall grasses dominate along with midheight and short grasses (Leoschke 1997).

The United States National Vegetation Classification's Great Plains Tallgrass Prairie Group (USNVC 2015) contains associations that align closely with the community types identified in this study. Dry-Mesic Prairie aligned closely with the Little Bluestem-Porcupine Grass Dry-Mesic Prairie association (CEGL002377), dominated by little bluestem, big bluestem, side-oats grama, western wheatgrass and porcupine grass (Faber-Langendoen 1995). The Northern Little Bluestem Gravel Prairie (CEGL002499) of the USNVC, which occurs on glacial outwash in sandy to gravelly soil and is dominated by grama spp., little bluestem and porcupine grass (Drake 1997) aligned with the Upland Dry Prairie community. The Mesic Prairie community most closely resembles the Northern Mesic Big Bluestem association (CEGL002202). Abundant species in both groups include big bluestem, porcupine grass and Indiangrass (Drake et al. 1994).

The classifications were compared to the Native Plant Communities of Minnesota (MNDNR 2005). Upland Dry Prairie and Dry-Mesic Prairie closely resembled descriptions of Minnesota's Southern Dry Prairie (UPs13) and the Mesic Prairie resembles Southern Mesic Prairie (UPs23), which both occur on the portion of the Prairie Coteau that extends into Minnesota.

Ups13 shares the same dominant grasses and many major forb species with the Upland Dry Prairie and the Dry-Mesic Prairie community. Species listed for Ups13 that did not occur in the South Dakota communities included hairy grama (*Bouteloua hirsuta*), pale purple coneflower (*Echinacea pallida*), stiff tickseed (*Coreopsis palmata*), blue bellflower (*Campunula rotundifolia)*, flowering spurge (*Eupohorbia corollata*), Carolina puccoon (*Lithospermum caroliniense*) and silky prairie clover (*Dalea villosa*) (MNDNR 2005). Within the UPs13 plant community type, the gravelly soil substrate of Upland Dry Prairie is similar to the UPs13 sub-type Dry Sand – Gravel Prairie (UPs13b) while Dry-Mesic Prairie is most similar to the Dry Hill Prairie (UPs13d) sub-type.

UPs23 is dominated by tall grasses, specifically big bluestem, which is similar to the Mesic Prairie community. They share the same dominant grasses, although Indiangrass is not as large of a component in the South Dakota mesic community as in the Minnesota type. Many of the same forb species were common in both types. Species that occurred in Ups23 that did not occur in Mesic Prairie included purple prairie clover, wood-violet (*Viola palmata*), purple meadow-rue (*Thalictrum dasycarpum*), pinnate prairie coneflower (*Ratibida pinnata*), smooth blue aster (*Aster laevis*), tall cinquefoil (*Potentilla arguta*), pale purple coneflower, stiff tickseed, common milkweed (*Asclepias syriaca*), prairie blazing star (*Liatris pycnostachya*), Virginia mountainmint (*Pycnanthemum virginianum*), Indianhemp (*Apocynum sibiricum*), plains yellow primrose, skyblue aster (*Symphyotrichum oolentangiensis*), showy tick trefoil (*Desmodium canadense*) and button eryngo (*Eryngium yuccifolium*) (MNDNR 2005).

The dominance of porcupine grass in the Dry-Mesic Prairie group may be partially attributed to the relevé plots sampled in hay pastures with a long-term management regime of fall haying. All but five of the relevés were sampled in hay pastures owned by the Sisseton-Wahpeton-Oyate tribe that have been under a strict haying schedule since the 1970's. Haying occurs once a year, after the seeds drop from the needlegrasses: needleandthread and porcupine grass. This usually occurs during early to mid-August, and during peak growing time for warm season grasses. In this manner, the haying regime favors needleandthread and porcupine grass reproduction from seed and against seed production of warm season grasses.

Only six plots represented the Mesic Prairie type, and so the description may not well represent this plant community. Further sampling may be needed but is made difficult by the rarity of this prairie plant community type. Most flat, loamy sites that would support Mesic Prairie have been converted to row crop agriculture or degraded by invasion by smooth brome and Kentucky bluegrass (DeKeyser et al. 2013).

The accuracy of the vegetation classification map (Figure 1.10) has not been verified in the field. Further research should assess the accuracy of this map by continued sampling of prairie communities. Moisture gradient, management regime and phenological variation should be taken into account when developing sampling protocol for classifying prairie communities. Sampling should be stratified not only across moisture gradients, but also across different types of management.

Defining these plant communities can be used as a tool for further inventories to map and assess grasslands on the South Dakota Prairie Coteau. Knowledge of the size, location and type of grassland communities remaining on the Prairie Coteau will help decision-makers develop conservation strategies for the Dakota skipper and other prairie endemic species of concern.

CHAPTER 2

CHARACTERIZATION AND COMPARISON OF VEGETATION ON DAKOTA SKIPPER INHABITED AND FORMERLY INHABITED SITES AND IDENTIFICATION OF POTENTIAL HABITAT

INTRODUCTION

The Dakota skipper (*Hesperia dacotae*), an endemic prairie butterfly, was listed as a federally threatened species on October 23, 2014 (Parham et al. 2014). Populations have declined concurrently with the conversion of grasslands to cropland and are now relegated to small remnants of high quality native prairie. These fragmented populations are suspected of beung isolated genetically (Britten and Glasford 2002) and are sensitive to management practices such as overgrazing that degrade vegetation or prescribed burning which can cause larval mortality (Dana 1991, Dana 1997).

Due to the relatively high amount of remnant grassland, the northern portion of the Prairie Coteau in northeastern South Dakota has been identified as a stronghold for the Dakota skipper butterfly (Royer and Marrone 1992). However, over the past decade populations have declined dramatically. Four sites on the South Dakota Prairie Coteau that had positive Dakota skipper surveys as recent as 2002 are now considered uninhabited by the Dakota skipper (Skadsen pers. comm 2014).

The factors that cause population losses need to be better understood so that prairie remnants supporting Dakota skippers can be managed appropriately. Dakota skipper populations have shown to be sensitive to changes in vegetation composition, specifically reductions in nectar sources and larval food plants (Dana 1997, Rigney 2013). The objectives of this study were to 1) characterize the vegetation composition of

Dakota skipper habitat at sites inhabited by the butterfly and at sites where Dakota skippers have recently disappeared and 2) identify new potential Dakota skipper habitat.

STUDY AREA

The study area encompassed 58,275 hectares (24-km by 24-km) of the northern South Dakota Prairie Coteau (Figure 2.1). The southeast corner of the study area is located where 459th Ave intersects State Highway 12, approximately 1.6 km (one mile) east of Summit, SD at 45° 18' 42.97" N and 97° 1' 13.35" W. The coordinates for the northwest corner are 45° 31' 46.11" N and 97° 19' 47.16" W. The Prairie Coteau is an iron-shaped plateau rising to 610 meters a.s.l., located between the Minnesota River and the Red River lowlands. The underlying bedrock is primarily Pierre shale. Numerous glacial movements have deposited large amounts of till on top of the bedrock, creating an irregular surface with relief of up to 120 meters. The resulting landscape is undulating, characterized by rolling hills and swales (Hogan and Fouberg 2001, Flint 1955).

Soils of the Prairie Coteau are of the Vienna and Kranzburg series, developed from glacial till and loess material and classified as fertile chernozem soils (Derscheid and Westin 1970). The major land use on the Coteau is row crop agriculture. Pasture and hayland remain where the rocky till and poor drainage have discouraged tillage, especially in the northern portion of the Coteau and along the escarpment where the topography is the most irregular with steep slopes (Smart et al. 2003). Within pastures, vegetation was originally characteristic of tallgrass prairie with a mixture of cool season and warm season grasses (Weaver 1954). However, due to the alteration of historic disturbance regimes and fragmentation, many grassland remnants in the Northern Great Plains are now dominated by Kentucky bluegrass (*Poa pratensis*) and smooth brome

(*Bromus inermis*) (DeKeyser et al. 2013). Additional habitats found on the Coteau include wetlands, lakes and wooded coulees.

The Coteau has a humid continental climate characterized by hot summers and cold winters. Within the study area, the number of frost free days ranges from 110-140. Annual average precipitation is 51-56 cm, with 28-38 cm falling as rain during the growing season, from mid-May to mid-September (Bryce et al. 1998, Hogan and Fouberg 2001).

Land ownership across the study area is divided between private landowners, the Sisseton-Wahpeton-Oyate tribe (grazing land, hayed land, and fallow land), U.S. Fish and Wildlife Service (wildlife production areas and refuges), and South Dakota Department of Game Fish and Parks lands (game production areas and state parks).

METHODS

Vegetation Sampling

Fifty-meter transects were subjectively placed within Dakota skipper habitat at sites inhabited by the butterfly and at sites where the butterfly had disappeared. A site was considered inhabited by the Dakota skipper if two consecutive positive surveys had been completed within the past five years. Dakota skippers were considered extirpated from a site if the last two surveys conducted within the past 10 years were negative for Dakota skipper occurrences. Transects were sampled within eight inhabited sites and four formerly inhabited sites within the study area (Figure 2.2). Detailed maps of site and transect locations are in Appendix B.

To ensure that suitable habitat was being measured, transects were subjectively placed within 40 meters of the GPS locations of Dakota skipper occurrences, typically along low ridges and upper slopes composed of high quality dry-mesic prairie. The number and spatial arrangement of Dakota skipper occurrence points varied across sites. At two sites that had no recorded GPS points, transects were placed where Dakota skippers had been previously observed by surveyor Dennis Skadsen (Skadsen pers comm. 2014). Dispersion of Dakota skipper GPS occurrence points and distribution of suitable habitat on sites largely determined the number and location of transects established at each site.

One-m^2 quadrats were placed on alternate sides along each transect every 10 meters beginning at the 0-meter marker and ending at the 50-meter marker for a total of six quadrats per transect. In each quadrat, litter depth, litter cover, exposed bare ground and cover by species were visually estimated using Daubenmire (1959) cover classes, modified by adding an extra class (0-1%) to better evaluate cover at low abundances. The classes were as follows: 1 (0-1%), 2 (1-5%), 3 (5-25%), 4 (25-50%), 5 (50-75%), 6 (75-95%) and 7 (95-100%). The elevation at the beginning and end of each transect was recorded. The aspect and slope was recorded from the center of each transect. The ecological site for each transect was determined later by overlaying transect locations in ArcGIS on top of a soil survey layer. Current management of the site of each transect was recorded and historical management of the site was obtained from the landowners or managers.

Sites were delineated in ArcGIS, and the size of each site was calculated. Site boundaries were defined by bodies of water, woodlands or change in management regime, often separated by fence lines.

Surveys of nectar flower species were conducted along transects in July 2014, during Dakota skipper flight time. The number of flowering stems in a 2-m x 50-m belt (one meter on each side of the transect) was counted and each stem was identified to species.

Data Analysis

Species cover class data were converted to class midpoint values, and quadrat data were averaged to calculate species cover at the transect level. Transect species cover data was averaged for all inhabited sites and formerly inhabited sites. Shannon-Weiner diversity was calculated for each transect and then averaged for all transects sampled at inhabited sites and formerly inhabited sites separately. Species richness was found for each transect, and then the average of transects sampled at inhabited sites and formerly inhabited sites was calculated separately. Density of flowering stems (no./m^2) was calculated for each transect by dividing total number of flowering stems per species by total area surveyed (100 m^2). Species of plants whose flowers produce no nectar were not included in the final analysis. Mean cover (%) of native vs. exotic and annual vs. perennial, grass, forb and shrub functional groups were compared. Documented larval plants and nectar source abundances and density of flowering stems (no./m^2) of documented nectar sources were also compared between inhabited and formerly inhabited sites using the Mann-Whitney U test (Mann and Whitney 1947) as the data were shown to have a non-normal distribution.

Nonmetric Multidimensional Scaling (NMS) was performed using PC-Ord v. 6.12 (McCune and Medford 2011) on the vegetation cover data and flowering species data at the transect level. A species main matrix was created by organizing the data into transects vs. species. In the species main matrix, prior to analysis, species cover class data were converted to cover class midpoints and log transformed using a generalized log transformation to put more emphasis on less abundant species (McCune and Grace 2002). The data was relativized by species maximum to equalize common and uncommon species (McCune and Grace 2002). Species that occurred in less than 5% of plots were excluded from the analysis to reduce noise. Elevation, slope, and aspect values and management categories were used to make a transect vs. environmental factors matrix. A total of 49 (39 from inhabited sites and 10 from formerly inhabited sites) transects and 108 species were used in the analysis. For flower survey data, species that have not been noted as Dakota skipper nectar sources, yet still produce nectar during Dakota skipper flight time, were kept in the analysis because the Dakota skipper has been described as moderately opportunistic (Dana 1991). Flowering stem density data were used to create a transect vs. species matrix, log transformed and relativized by maximum to put more emphasis on less abundant species (McCune and Grace 2002). NMS was run using Sørenson (Bray-Curtis) distance, with a maximum of 500 iterations, 600 runs with real data and 200 runs with randomized data on each matrix separately.

Indicator species analysis was applied to the vegetation cover and flowering stem data for inhabited and formerly inhabited sites to find species diagnostic of each group (Dufrêne and Legendre 1997). Multi-response permutation procedures (MRPP) (Mielke 1984) were performed on vegetation cover and flowering stem data to determine if statistical differences existed between groups.

Potential Habitat Layer

Potential habitat for the Dakota skipper was identified in the study area by intersecting a layer of specific USDA ecological sites and an untilled grassland layer in ArcGIS 10.1. A digitized layer delineating USDA ecological sites was acquired through a state NRCS office in Rapid City, South Dakota. Ecological sites are units of land that have similar soil properties, hydrology and vegetation. They are generally mapped by grouping NRCS soil survey units together that have the potential to produce similar native plant communities (Butler et al. 2003).

To determine ecological sites that produce plant communities used by the Dakota skipper, the ecological sites layer was overlaid on Dakota skipper GPS occurrence points from 2013 and 2014 surveys. Out of a total of 145 Dakota skipper survey points 37%, 27%, 20% and 17% occurred on thin loamy, loamy, shallow gravel and very shallow ecological sites, respectively. To identify the potential habitat, a layer was created by intersecting a layer of grasslands with no history of cultivation on the SD Prairie Coteau (Bauman et al. 2014) with the four ecological site types where Dakota skippers had been recorded.

RESULTS

Management

Eight of the inhabited sites and one of the formerly inhabited sites had been under a late summer haying regime since the 1970's. These prairies are owned by the Sisseton-Wahpeton-Oyate and are rented to private landowners who are instructed to hay the prairies once a season. The exact time of haying varies and is dependent upon when the needle-like seeds of *Hesperostipa* spp. drop, typically occurring by mid-August. One of the formerly inhabited tribally owned sites has been hayed during mid-July rather than late August for at least the past two years. Most of the site is heavily invaded by smooth brome, which frees up the land manager from the restriction of having to wait until the needlegrasses shed their seeds. One of the formerly inhabited sites is owned by the U.S. Fish and Wildlife Service and has been under various types of management, including spring prescribed burning which occurred in 2009 and 2014. Another formerly inhabited site was part of the Pickerel Lake State Recreation Area and has been under a mixed management regime of fall haying and periodic prescribed burning (Table 2.1).

Vegetation Composition Surveys

A total of 140 and 98 species were recorded from transects sampled at inhabited sites and formerly inhabited sites respectively. Average species richness for inhabited transects and formerly inhabited transects was 40.9 and 38.6, respectively. Average species evenness was 0.621 for inhabited transects and 0.696 for formerly inhabited transects. Shannon-Weiner diversity was 2.308 for all inhabited transects and 2.535 for formerly inhabited transects meaning greater diversity was found at formerly inhabited transects.

There was considerable overlap of highly abundant species at inhabited and formerly inhabited sites, including the two dominant species, little bluestem and porcupine grass (Table 2.2). However, cover of these two species was higher at inhabited sites than at formerly inhabited sites. Two common nectar sources occurred in the top ten most abundant species of transects sampled at inhabited sites, purple coneflower and groundplum milkvetch, and one common nectar source, standing milkvetch, was among the most abundant species at formerly inhabited sites. A complete list of abundance and frequency values for species at inhabited and formerly inhabited sites is in Appendix C.

Native annual forb cover was significantly higher at inhabited sites, while mean native perennial forb cover was significantly higher at formerly inhabited sites. The mean cover of other functional groups showed no significant differences between sites (Table 2.3). No significant differences were found between larval food abundances at inhabited and formerly inhabited sites (Table 2.4). Blue lettuce (*Lactuca tatarica*), a rarely used nectar species (Swengel and Swengel 1999) was significantly more abundant at inhabited sites (Table 2.5). Standing milkvetch, a commonly used nectar source (Dana 1991), an unidentified milkvetch, and northern bedstraw and alfalfa (*Medicago sativa*), both rarely used Dakota skipper nectar sources (Swengel and Swengel 1999), were significantly more abundant at formerly inhabited sites (Table 2.5). The total nectar source cover was almost significantly greater at formerly inhabited sites with a p-value of 0.050 (Table 2.5).

A two-dimensional NMS solution was chosen for the interpretation of the vegetation cover transect data (minimum stress=20.9) with axis one explaining 59% and axis two explaining 17% of the variation (76% cumulative).

After examination of the main matrix correlations, axis 1 was found to represent a moisture gradient (Table 2.6). Species negatively correlated with axis one were species that grow in xeric prairie environments, including dotted gayfeather (r = -0.85), prairie chickweed (*Cerastium arvense*) (r = -0.76), Junegrass (*Koeleria macrantha*) (r = 0.63), blanket flower (r = -0.61) and needleandthread (r = -0.57). At the other end of the axis, positively correlated species, including porcupine grass (r = 0.68), prairie rose (*Rosa* *arkansana*) (r = 0.63), stiff goldenrod (*Oligoneuron rigidum*) (r = 0.61), prairie violet (*Viola pedatifida*) (r = 0.61) and Leiberg's panic grass (*Dichanthelium leibergii*) (r = 0.54), grow in prairie environments whose soils contain more moisture. An overlay of the ecological sites of each transect location showed that the loamy and thin loamy sites appeared on the positive end of axis 1, while the drier, very shallow and shallow gravel sites appeared on the negative end of the axis, confirming the moisture gradient.

When the transect ordination was overlaid with the status of the Dakota skipper, not all the formerly inhabited transects grouped together (Figure 2.3). The majority of formerly inhabited transects (6 out of 10) clustered at the negative end of axis one, and two formerly inhabited transects appeared in the middle of the cluster of inhabited transects.

The MRPP using Sørenson distance produced an A value of 0.0667 and a p-value of 0.001. The p-value was below 0.05, and the A was greater than 0.03, showing fairly high homogeneity within each transect group (McCune and Grace 2002).

Indicator species of sites inhabited by the Dakota skipper included a rarely used nectar source, blue lettuce (*Lactuca tatarica*) (Dana 1991, Swengel and Swengel 1999), and an important component of Dakota skipper habitat previously described by Dana (1991, 1997) and Royer and Marrone (1992), porcupine grass. Indicator species of sites where the Dakota skipper was considered extirpated included one common nectar source, standing milkvetch, a possible nectar source, an unidentified milkvetch species, and a larval food plant, Wilcox's panicum (*Wilcox dichanthelium*) (Dana 1991) (Table 2.7).

A three-dimensional solution was chosen for the ordination of vegetation composition by site (minimum stress = 4.0) with axis 1, 2 and 3 explaining 82%, 6% and 8% of the variation, respectively.

Consistent with the results of the transect ordination, axis 1 was found to represent a moisture gradient after examination of the main matrix correlations (Table 2.8). Species most negatively correlated with axis 1 were Junegrass (r = -0.93), blanket flower (r = -0.85), blue grama (*Bouteloua gracilis*) (r = -0.83), and prairie chickweed (r = -0.83). These species occur in the drier prairie soils. Most positively correlated with axis 1 were prairie rose (r = 0.88), stiff goldenrod (r = 0.77), Leiberg's panic grass (r = 0.76) and buckbrush (*Symphoricarpos occidentalis*) (r = 0.75), which occur in moister prairie soils.

Although a pattern was observed in the ordination configuration associated with axis 2 (Figure 2.4), no clear gradient was apparent. Formerly inhabited sites appeared toward the negative end of axis 2. Species most negatively correlated with axis 2 were prairie groundsel (r = -0.58) and Virginia groundcherry (r = -0.58) and species most positively correlated with axis 2 were Richardson's alumroot (r = 0.89), timothy (r = 0.83), heartleaf alexanders (r = 0.80) and porcupine grass (r = 0.76). None of the correlations between the secondary matrix variables and the axes were significant at $p < 0.05$ (Table 2.9). No clear gradient was apparent in regards to axis 3.

Flowering Stem Surveys

The flowering stem surveys were conducted from July 7th to July 9th of 2014, coinciding with Dakota skipper flight time. There was considerable overlap in the top ten most abundant flowering plants between inhabited and formerly inhabited sites (Table

2.10). Six species occurred in the top ten highest densities at inhabited and formerly inhabited sites, including two commonly used nectar sources, purple coneflower and standing milkvetch, and two uncommonly used nectar sources, northern bedstraw and common yarrow (Table 2.10). Complete lists of abundance and frequency values of species of inhabited and formerly inhabited sites are located in Appendix D.

The total density of flowering stems was greater at formerly inhabited sites (Table 2.11). The nectar source glaucous false dandelion occurred at a significantly higher density at inhabited sites. Plains yellow primrose, northern bedstraw and alfalfa occurred at significantly higher densities at formerly inhabited sites (Table 2.11).

A 2-dimensional NMS solution was chosen for the interpretation of the flowering stem data (minimum stress=28.04) with axis one explaining 29% and axis two explaining 23% of the variation in the data (53% cumulative).

In the ordination plot, transects sampled at formerly inhabited Dakota skipper sites appeared at the positive end of axis two (Figure 2.5). Species most positively correlated with that end of the axis included sweetclover (*Melilotus officinalis*) ($r = 0.61$), blanket flower ($r = 0.49$) and alfalfa ($r = 0.48$) (Table 2.12). The only indicator species for inhabited sites was glaucous false dandelion, a commonly used nectar source (Table 2.13). Significant indicator species (p-values < 0.05) for formerly inhabited sites included three rarely used Dakota skipper nectar sources: plains yellow primrose, northern bedstraw and alfalfa (Table 2.13).

The NMS ordination of the flowering stem data indicates that there was a difference in the composition between inhabited and formerly inhabited sites. However, there were no significant differences between inhabited and formerly inhabited sites in any species noted as a commonly used Dakota skipper nectar source. So although composition differed, it differed in the abundance of nectar producing species that are not commonly used as nectar sources by the Dakota skipper.

The MRPP applied to the groups using Sørenson distance produced a p-value of 0.000008 and an A value of 0.0806, which shows fairly high homogeneity within groups (McCune and Grace 2002).

Potential Habitat

The potential Dakota skipper habitat layer in ArcGIS covered 22,345 hectares of the study area (Figure 2.6). This layer identified land that has the soil properties characterizing plant communities suitable for the Dakota skipper butterfly. To determine actual suitable habitat in the layer, the condition and management history of the grasslands need to be assessed and recorded.

DISCUSSION

There was no clear trend in the comparison of vegetation composition at inhabited and formerly inhabited sites. Not all formerly inhabited transects clustered together in the ordination of the vegetation cover data. Most larval food plants and nectar sources were not significantly more abundant at either inhabited or formerly inhabited sites. Surprisingly, one of the commonly used nectar sources, standing milkvetch, was significantly more abundant at formerly inhabited sites. Two uncommonly used nectar sources, northern bedstraw and alfalfa, were significantly more abundant at formerly inhabited sites when comparing both vegetation cover and the number of flowering stems. The especially high abundances of these two species contributed to the significant abundance of total native perennial cover and the total nectar source stem density at formerly inhabited sites. These species are also two of the main drivers of the pattern in the flowering stem ordination, which was driven by species not commonly used as nectar sources by the Dakota skipper.

This suggests other factors besides vegetation composition may be contributing to the disappearance of local Dakota skipper populations. Such factors may include management regime (McCabe 1981, Dana 1991, Swengel and Swengel 1999), critical minimum size and connectivity of suitable habitat (Britten and Glasford 2002).

The management of sites where Dakota skippers occur influences the success of populations (McCabe 1981, Dana 1991, Royer and Marrone 1992, Dana 1997, Swengel and Swengel 1999). The type of management most successful at maintaining Dakota skipper populations is a late summer or fall haying regime (McCabe 1981, Dana 1991, Swengel and Swengel 1999), so it is no surprise that all inhabited sites had been under the same late summer haying regime since the 1970's. Two of the formerly inhabited sites, one a USFWS Wildlife Refuge and one a State Park Recreation Area, had undergone varied management regimes that included periodic prescribed burning. Prescribed fires have shown to contribute to declines in Dakota skipper populations (Dana 1991, Swengel and Swengel 1999). Another formerly inhabited site had been under a mid-summer haying regime for at least the past two years. This type of haying schedule removes adult nectar sources that provide both food and water for Dakota skippers during flight time (Dana 1991). Reduced availability or loss of nectar sources would logically decrease the chances of adult survival and reduce female fecundity (Dana 1991), thereby causing declines in population.

The one formerly inhabited site that had been under the same management regime as the inhabited sites was the smallest site sampled, 4.8 ha. Although no critical minimum habitat size has been determined for the Dakota skipper, small habitat patches hold smaller populations and small isolated populations will experience the negative effects of genetic drift more readily than large populations, putting them at greater risk of extirpation (Britten and Glasford 2002).

Populations of the Dakota skipper are suspected to be isolated from one another (Britten and Glasford 2002). Increased connectivity between populations is also beneficial for the same reason large populations are more sustainable. Connectivity between populations allows for gene flow, reducing the effects of genetic drift (Frankel and Soulé 1981). Further research should examine the structural and functional connectivity between sites where Dakota skippers persist and sites where they have been extirpated.

Each site studied was ranked according to the condition ranking previously described in this study. This provides a general guide to suitability of each site for the Dakota skipper. Each of the inhabited sites were in A or B condition, while the formerly inhabited sites ranged from A to C condition (Figure 1.4). The inhabited sites that were sampled were similar in quality and management. Other inhabited sites in poorer condition and under different management do exist, but were not sampled for this study. Because the full range of sites in terms of quality and management regime were not sampled, specific quality thresholds were unable to be determined.

The ordination of vegetation composition at the site level did show a pattern associated with axis 2. However, this axis explained only 6% of the variation in the ordination, a small percentage. An underlying gradient driving the pattern could not be determined.

The subjective placement of transects at Dakota skipper GPS locations ensured that only current and previous Dakota skipper habitat was measured. This method was chosen because Dakota skippers are not inclined to disperse far (Royer and Marrone 1992) and are known to oviposit and nectar in the same upland prairie habitat (Dana 1991). Also, invasive grasses have taken hold in the toe slopes and lower lying mesic areas at all sites. The subjective placement of transects meant the best quality vegetation was sampled at each site, while avoiding areas dominated by exotic species that Dakota skippers cannot use as habitat (Dana 1991). However, due to the sampling methods the total amount of suitable habitat at any site could not be quantified.

Additonal Dakota skipper sites are predicted to exist in the South Dakota Prairie Coteau area (Cochrane and Delphey 2002). The potential habitat layer paired with the vegetation characterization at Dakota skipper sites can be used to target Dakota skipper surveys across the South Dakota Prairie Coteau. The potential habitat layer effectively rules out areas where Dakota skippers will not be found. To further target the surveys, the detailed information about species composition at inhabited sites can be used to identify specific areas where Dakota skippers would be likely to occur.

This is especially beneficial given that there are inherent difficulties in Dakota skipper surveying (Cochrane and Delphey 2002). These include the short window of time the Dakota skipper is in its butterfly life stage, and the fact that only well-trained professionals are qualified to identify the butterfly (Cochrane and Delphey 2002).

Although the potential Dakota skipper habitat layer has its limitations, it can serve as a reference point to begin investigating the connectivity of suitable habitat at a landscape scale. This would provide valuable information to advance the understanding of how isolation affects Dakota skipper populations and what role it plays in the extirpation of local populations.

TABLES

Table 1.1. Number and status of Dakota skipper sites and their butterfly status in U.S. and Canada (reproduced from Federal Register 2013).

State	Present*	Unknown**	Possibly extirpated***	Extirpated****	Total	Percent of Total Number of Historical Sites by State*****
Illinois	----	----	----	1	1	0.4
Iowa	----	----	----	3	3	1
Minnesota	14	22	18	12	66	26
North Dakota	18	13	10	13	54	21
South Dakota	14	46	10	15	85	33
Manitoba	31	0	2	3	36	14
Saskatchewan	14	0	0	0	14	5
Total Number of Historically Documented Sites	91	81	47	47	259	----
Percent of Total Number of Historical Sites by Occupancy	35	31	18	18	----	100

* Considered present if “detected during the most recent survey if the survey was conducted in 2002 or more recently and there is no evidence to suggest the species is now extirpated from the site” (Federal Register 2013)
** Considered unknown “if the species was found in 1993 or more recently, but not in the most recent one to two sequential survey year(s) since 1993 and there is no evidence to suggest the species is now extirpated from the site” (Federal Register 2013)
***Considered unknown if “it was detected at least once prior to 1993, but not in the most recent one to two sequential survey years(s) (Federal Register 2013)
****Considered extirpated if a site had at least three sequential years of negative surveys (Federal Register 2013)
*****To calculate the percent total number of historical sites by state the total number of sites in each state was divided by the Total Number of historically documented sites (259) and multiplied by 100

Table 1.2. Criteria used to determine condition rank. Each metric was ranked individually and then averaged together to produce overall rank.
Scores for individual metrics: A 5; A- 4.375; B 3.75; B- 3.125; C 2.5; C- 1.875; D 1.25; E 0
Scores for overall ranks: A=5-3.76 B=3.75-2.6 C=2.5-1.26 D=<1.25

Condition Ranking Metrics for Upland Prairie							
Metric	**A**	**A-**	**B**	**B-**	**C**	**C-**	**D**
Relative Cover Native Species (RCNS)	Native spp. >85% relative cover		Native spp. 85-70% relative cover		Native spp. 70-50% relative cover		Native spp. <50% relative cover
Cover Exotic Invasive Species	Exotic invasive spp. <5% absolute cover		Exotic invasive spp. 5-15% absolute cover		Exotic invasive spp. 15-30% absolute cover		Exotic invasive spp. >30% absolute cover
Native Increaser Species	Concentra-tions of increasers absent or <10% of RCNS		Concentra-tions of increasers occupy 10%-25% of RCNS		Concentra-tions of increasers occupy 25-50% of RCNS		Concentra-tions of increasers occupy >50% of RCNS
Native Decreaser Species	More than 15 decreaser spp. present and common throughout prairie stand	More than 15 decreaser spp. present but not common throughout the stand	5-15 of decreaser spp. present and common throughout the stand	5-15 of decreaser spp. present, but not common throughout the stand	1-4 decreaser spp. present, and common throughout stand	1-4 decreaser spp. present but not common throughout the stand	No decreaser spp. present

Table 1.3. List of increaser species giving coefficient of conservatism values. C-values are taken from The Northern Great Plains Floristic Quality assessment Panel (2001).

Prairie Increaser Species		
Common Name	Scientific Name	C
common yarrow	*Achillea millefolium*	3
ragweed species	*Ambrosia* spp.	0-2
pasque flower	*Anemone patens*	9
pussytoes spp	*Antennaria spp.*	5-6
Purple three-awn	*Aristida purpurea*	4
sagewort species	*Artemisia* spp.	3-4
whorled milkweed	*Asclepias verticillata*	3
sideoats grama	*Bouteloua curtipendula*	5
blue grama	*Bouteloua gracilis*	7
sun-loving sedge	*Carex inops*	7
prairie chickweed	*Cerastium arvense*	2
bastard toadflax	*Comandra umbellata*	8
Scribner's panic grass	*Dichanthelium oligosanthes*	6
western wheatgrass	*Pascopyrum smithii*	4
field horsetail	*Equisetum arvense*	4
annual fleabane	*Erigeron annuus*	3
daisy fleabane	*Erigeron strigosus*	3
grass-leaved goldenrod	*Euthamia graminifolia*	6
prairie smoke	*Geum triflorum*	8
golden aster	*Heterotheca villosa*	3
eastern red cedar	*Juniperus virginiana*	0
skeletonweed	*Lygodesmia juncea*	2
wild bergamot	*Monarda fistulosa*	5
green needle grass	*Nassella viridula*	5
evening primrose	*Oenothera biennis*	0
false gromwell	*Onosmodium molle*	7
white beard tongue	*Penstemon albidus*	7
slender beard tongue	*Penstemon gracilis*	6
Pennsylvania cinquefoil	*Potentilla pensylvanica*	9
prairie coneflower	*Ratibida columnifera*	3
American black currant	*Ribes americanum*	7
Canada goldenrod	*Solidago canadensis*	1
Missouri goldenrod	*Solidago missouriensis*	5
gray goldenrod	*Solidago nemoralis*	6
stiff golden rod	*Oligoneuron rigidum*	4
tall dropseed	*Sporobolus compositus*	4
buckbrush	*Symphoricarpos occidentalis*	3
heath aster	*Symphyotrichum ericoides*	2
hoary vervain	*Verbena stricta*	2
prairie violet	*Viola pedatifida*	8

Table 1.4. List of decreaser species giving coefficient of conservatism values. C-values are taken from The Northern Great Plains Floristic Quality Assessment Panel (2001).

Prairie Decreaser Species		
Common Name	Spientific Name	C
glaucous false dandelion	*Agoseris glauca*	8
prairie wild onion	*Allium stellatum*	7
leadplant	*Amorpha canescens*	9
big bluestem	*Andropogon gerardii*	5
oval-leaved milkweed	*Asclepias ovalifolia*	9
showy milkweed	*Asclepias speciosa*	4
standing milkvetch	*Astragalus adsurgens*	8
Canada milkvetch	*Astragalus canadensis*	5
groundplum milkvetch	*Astragalus crassicarpus*	7
prairie evening primrose	*Calylophus serrulatus*	7
white prairie clover	*Dalea candida*	8
purple prairie clover	*Dalea purpea*	8
Leiberg's panic grass	*Dichanthelium leibergii*	8
purple coneflower	*Echinacea angustifolia*	7
Canada wild rye	*Elymus canadensis*	3
blanket flower	*Gaillardia aristata*	5
bottle gentian	*Gentiana andrewsii*	10
downy gentian	*Gentiana puberulenta*	10
stiff sunflower	*Helianthus pauciflorus*	8
ox-eye	*Heliopsis helianthoides*	5
porcupine grass	*Hesperostipa spartea*	7
Richardson’s alumroot	*Heuchera richardsonii*	8
false boneset	*Brickellia eupatorioides*	5
rough blazing star	*Liatris aspera*	8
northern plains blazing star	*Liatris ligulistylis*	10
wood lily	*Lilium philadelphicum*	8
plains muhly	*Muhlenbergia cuspidata*	8
prairie turnip	*Pediomelum esculentum*	9
tall cinquefoil	*Potentilla arguta*	8
smooth rattlenakeroot	*Prenanthes racemosa*	10
little bluestem	*Schizachyrium scoparium*	5
upland white aster	*Solidago ptarmicoides*	8
Indian grass	*Sorghastrum nutans*	6
prairie dropseed	*Sporobolus heterolepis*	10
heart-leaved alexanders	*Zizia aptera*	8

Table 1.5. Correlations between main matrix species and NMS axes. All species included in table have Pearson correlation coefficients with p-value <0.005 (Fisher and Yates 1963).

Species Correlations with NMS Axes			
Axis 1			
species	r	r-squared	tau
Hesperostipa comata	0.62	0.38	0.53
Gailardia aristata	0.59	0.34	0.48
Heuchera richardsonii	0.58	0.34	0.47
Heterotheca villosa	0.57	0.32	0.52
Artemisia frigida	0.56	0.31	0.48
Liatris punctata	0.56	0.31	0.47
Linum rigidum	0.53	0.28	0.45
Bouteloua gracilis	0.50	0.25	0.42
Echinacea angustifolia	0.45	0.21	0.36
Potentilla pensylvanica	0.45	0.20	0.36
Gaura coccinea	0.44	0.19	0.41
Ambrosia psilostachya	0.43	0.18	0.37
Lactuca tatarica	0.42	0.18	0.23
Koeleria macrantha	0.41	0.17	0.33
Nassella viridula	0.39	0.16	0.31
Polygala verticillata	0.39	0.16	0.26
Tragopogon dubius	0.38	0.14	0.24
Pulsatilla patens	0.36	0.13	0.20
Mirabilis hirsuta	0.35	0.12	0.31
Ratibida columnifera	0.33	0.11	0.30
Astragalus adsurgens	0.32	0.10	0.29
Calamovilfa longifolia	0.32	0.10	0.28
Phleum pratense	-0.73	0.53	-0.60
Zizia aptera	-0.72	0.51	-0.61
Thalictrum venulosum	-0.62	0.38	-0.49
Zizia aurea	-0.55	0.30	-0.46
Liatris spp.*	-0.54	0.29	-0.40
Pedicularis canadensis	-0.53	0.28	-0.41
Zigadenus elegans	-0.52	0.27	-0.34
Lobelia spicata	-0.52	0.27	-0.37
Rudbeckia hirta	-0.51	0.26	-0.31
Prenanthes racemosa	-0.49	0.24	-0.36
Agoseris glauca	-0.47	0.23	-0.33
Trifolium pratense	-0.47	0.22	-0.40
Andropogon gerardii	-0.46	0.22	-0.31
Sorghastrum nutans	-0.43	0.19	-0.24
Dichanthelium spp.**	-0.34	0.12	-0.34
Dalea candidia	-0.33	0.11	-0.24

*Includes *L. aspera* and/or *L. ligulistylis* **Includes *D. leibergii* and/*or D. oligosanthes*

Axis 2			
species	r	r squared	tau
Agoseris glauca	0.48	0.23	0.46
Lobelia spicata	0.41	0.16	0.35
Astragalus crassicarpus	0.41	0.16	0.32
Pediomelum esculentum	0.40	0.16	0.31
Pulsatilla patens	0.39	0.15	0.35
Erigeron strigosus	0.37	0.14	0.31
Astragalus adsurgens	0.36	0.13	0.31
Heterotheca villosa	0.36	0.13	0.32
Taraxacum officinale	0.33	0.11	0.28
Avenula hookeri	0.33	0.11	0.30
Soidago canadensis	-0.73	0.53	-0.60
Monarda fistulosa	-0.70	0.49	-0.59
Artemisia ludoviciana	-0.66	0.44	-0.53
Symphoricarpos occidentalis	-0.59	0.35	-0.50
Asclepias spp.*	-0.56	0.32	-0.45
Oligoneuron rigidum	-0.56	0.31	-0.50
Onosmodium bejariense	-0.47	0.22	-0.40
Ambrosia psilostachya	-0.47	0.22	-0.42
Rosa arkansana	-0.47	0.22	-0.38
Symphyotrichum sericeum	-0.41	0.17	-0.36
Helianthus maximiliani	-0.39	0.15	-0.25
Artemisia absinthium	-0.37	0.14	-0.24
Prunus americana	-0.36	0.13	-0.20
Poa pratensis	-0.35	0.12	-0.30
Glycyrrhiza lepidota	-0.34	0.11	-0.29
Symphyotrichum ericoides	-0.32	0.10	-0.28

*Includes *A. syriaca* and/or *A. speciosa*

Table 1.6. Correlations of secondary matrix with synthesized NMS axes. Physiognomic variables refer to the different strata recorded in each relevé plot.

Environmental and Physiognomic Variable Correlations with NMS Axes						
Variables		Axis 1			Axis 2	
Environmental	r	r-squared	tau	r	r-squared	tau
elevation	-0.01	0	-0.01	0.23	0.05	0.14
slope	0.23	0.05	0.15	-0.33	0.11	-0.23
Physiognomic						
woody plants	-0.11	0.01	-0.12	-0.34	0.11	-0.19
forbs	0.21	0.04	0.21	-0.02	0	-0.01
graminoids	-0.25	0.06	-0.16	-0.25	0.06	-0.24

Table 1.7. Results of the indicator species analysis (ISA), including the mean p-value of indicator species and toal number of significant indicators species for each group, and the multi-response permutation procedures (MRPP), including A value or chance corrected winthin-group agreement used to evaluate cluster groups in the final cluster analysis. Each cluster group produced by flexible beta (β = -.025), group average and Ward's method was evaluated at the two-group and three-group levels. flex beta = flexible beta (β = -.025), grp average = group average, ward = Ward's method

Results of ISA and MRPP for Cluster Groups					
method	# of grps	ISA mean p-value	# of ind. species	MRPP A value	MRPP p-value
flex beta	2	0.3654	22	0.1565	0
grp average	2	0.3654	21	0.1565	0
ward	2	0.2654	25	0.1640	0
flex beta	3	0.1949	36	0.3149	0
grp average	3	0.1739	41	0.3147	0
ward	3	0.1811	38	0.3102	0

Table 1.8. The USDA Ecological Site of each relevé plot, arranged by plant community group. UDP=Upland Dry Prairie, DMP=Dry-Mesic Prairie, MP=Mesic Prairie.

Relevé Occurrence in Ecological Sites by Plant Community							
	#	# of relevés occurring in each ecological site					
plant community	relevés /group	shallow gravel	very shallow	thin loamy	loamy	subirrigated	limy subirrigated
UDP	16	5	7	1	3	0	0
DMP	45	2	1	12	30	0	0
MP	6	0	0	0	1	3	2

Table 1.9. Constant species of Upland Dry Prairie, defined as having constancy > 60% (Braun-Blaunquet 1932). The top ten most abundant species are shaded. Species with constancy of less than 60% are located at the bottom of the table.

Upland Dry Prairie Constant Species (n=16)		
Species	Constancy (%)	Average Cover (%)
Dalea purpurea	100	1.93
Echinacea angustifolia	100	3.01
Hesperostipa spartea	93.75	12.04
Pediomelum esculentum	93.75	0.24
Poa pratensis	93.75	6.25
Schizachyrium scoparium	93.75	15.01
Amorpha canescens	87.5	2.07
Comanda umbellata	87.5	1.74
Heuchera richardsonii	87.5	0.07
Liatris punctata	87.5	2.04
Symphyotrichum ericoides	87.5	1.43
Taraxacum officnale	87.5	0.38
Tragopogon dubius	87.5	0.38
Achillea millefolium	81.25	1.28
Astragalus crassicarpus	81.25	0.37
Cirsium flodmanii	81.25	0.53
Galium boreale	81.25	3.44
Heterotheca villosa	81.25	0.53
Pulsatilla patens	81.25	1.13
Solidago missouriensis	81.25	0.81
Viola pedatifida	81.25	0.38
Artemisia frigida	75	1.30
Bromus inermis	75	3.13
Linum rigidum	75	0.98
Physalis virginiana	75	0.36
Astragalus adsurgens	68.75	0.36
Gaillardia aristata	68.75	0.05
Sporobolus heterolepis	68.75	4.88
Anemone cylindrical	62.5	0.21
Hesperostipa comata	62.5	4.39
Koeleria macrantha	62.5	0.51
Nassella viridula	62.5	3.31
Pediomelum argophyllum	62.5	1.41
Penstemon gracilis	62.5	0.03
Symphyotrichum sericeum	62.5	0.81
Helianthus pauciflorus	50	3.59

Table 1.10. Mean cover (%) and frequency (%) of significant indicator species (p-values < 0.01) for each plant community type. Indicator species values are shaded in column of associated group. UDP=Upland Dry Prairie, DMP=Dry-Mesic Prairie, MP=Mesic Prairie.

	Frequency (%)			Mean Cover (%)			
Native Plant Community	UDP	DMP	MP	UDP	DMP	MP	p-value
number of relevés/group	16	45	6	16	45	6	
Echinacea angustifolia	100.00	82.22	33.33	3.01	1.26	0.02	0.0002
Heterotheca villosa	81.25	4.44	0.00	0.53	0.00	0.00	0.0002
Heuchera richardsonii	87.50	22.22	0.00	0.07	0.01	0.00	0.0002
Liatris punctata	87.50	33.33	0.00	2.04	0.29	0.00	0.0002
Pediomelum esculentum	93.75	82.22	0.00	0.24	0.12	0.00	0.0006
Astragalus adsurgens	68.75	8.89	0.00	0.36	0.01	0.00	0.0008
Artemisia frigida	75.00	22.22	0.00	1.30	0.02	0.00	0.001
Gaillardia aristata	68.75	8.89	0.00	0.05	0.01	0.00	0.0012
Bouteloua gracilis	56.25	11.11	0.00	0.81	0.06	0.00	0.002
Hesperostipa comata	62.50	13.33	0.00	4.39	1.89	0.00	0.0022
Pulsatilla patens	81.25	46.67	0.00	1.13	0.31	0.00	0.0028
Potentilla pensylvanica	56.25	8.89	0.00	0.20	0.01	0.00	0.0036
Dalea purpurea	100.00	84.44	16.67	1.93	1.93	0.02	0.004
Gaura coccinea	50.00	6.67	0.00	0.50	0.06	0.00	0.0046
Linum rigidum	75.00	37.78	33.33	0.98	0.09	0.02	0.0094
Symphyotrichum sericeum	62.50	88.89	16.67	0.81	1.53	0.02	0.0002
Viola pedatifida	81.25	91.11	16.67	0.38	1.10	0.02	0.0014
Amorpha canescens	87.50	95.56	50.00	2.07	5.63	0.85	0.0016
Hesperostipa spartea	93.75	95.56	66.67	12.04	22.06	3.34	0.002
Anemone cylindrica	62.50	88.89	33.33	0.21	0.94	0.03	0.0036
Andropogon gerardii	37.50	64.44	100.00	1.27	6.28	24.58	0.0002
Liatris spp.*	25.00	55.56	100.00	0.02	0.48	2.10	0.0002
Lobelia spicata	25.00	13.33	100.00	0.03	0.01	0.10	0.0002

Phleum pratense	6.25	35.56	100.00	0.01	0.62	8.75	0.0002
Prenanthes racemosa	0.00	2.22	66.67	0.00	0.00	0.04	0.0002
Zizia aptera	12.50	57.78	100.00	0.16	0.32	2.50	0.0002
Zizia aurea	0.00	17.78	83.33	0.00	0.01	0.88	0.0002
Pedicularis canadensis	6.25	6.67	83.33	0.16	0.44	1.68	0.0004
Zigadenus elegans	31.25	40.00	100.00	0.03	0.68	1.70	0.0004
Trifolium pratense	0.00	11.11	66.67	0.00	0.01	0.47	0.0006
Rudbeckia hirta	6.25	2.22	50.00	0.00	0.00	0.05	0.0014
Helianthus maximiliani	6.25	22.22	66.67	0.00	0.34	1.27	0.0016
Thalictrum venulosum	25.00	44.44	83.33	0.33	0.20	8.33	0.002
Dalea candida	0.00	15.56	50.00	0.00	0.34	0.84	0.0038
Agoseris glauca	37.50	35.56	83.33	0.03	0.56	1.28	0.0068
Sorghastrum nutans	6.25	17.78	50.00	0.01	0.56	5.42	0.007

***** Includes *L. aspera* and *L. ligulistylis*

Table 1.11. Constant species of Dry-Mesic Prairie, defined as having constancy > 60% (Braun-Blaunquet 1932). The top ten most abundant species are shaded. Species with constancy of less than 60% are located at the bottom of the table.

Dry-Mesic Prairie Constant Species (n=45)		
Species	Constancy (%)	Average Cover (%)
Cirsium flodmanii	97.78	1.32
Amorpha canescens	95.56	5.63
Hesperostipa spartea	95.56	22.06
Galium boreale	93.33	3.39
Viola pedatifida	91.11	1.10
Anemone cylindrica	88.89	0.94
Bromus inermis	88.89	5.62
Poa pratensis	88.89	4.79
Symphyotrichum sericeum	88.89	1.53
Helianthus pauciflorus	86.67	3.24
Physalis virginiana	86.67	0.56
Schizachyrium scoparium	86.67	9.95
Dalea purpurea	84.44	1.93
Echinacea angustifolia	82.22	1.26
Pediomelum esculentum	82.22	0.12
Achillea millefolium	80.00	1.04
Rosa arkansana	80.00	0.98
Oligoneuron rigidum	77.78	1.87
Symphyotrichum ericoides	75.56	1.30
Dichanthelium spp.*	71.11	2.46
Pediomelum argophyllum	71.11	1.91
Comandra umbellata	68.89	1.24
Symphoricarpos occidentalis	66.67	1.29
Andropogon gerardii	64.44	6.28
Lithospermum canescens	64.44	0.22
Tragopogon dubius	64.44	0.10
Astragalus crassicarpus	62.22	1.04
Solidago canadensis	62.22	2.46
Bouteloua curtipendula	53.33	4.06
Sporobolus heterolepis	55.56	2.52

*Includes *D. oligosanthes* and/or *D. leibergii*

Table 1.12. Constant species of Mesic Prairie, defined as having a constancy value > 60% (Braun-Blaunquet 1932). The top ten most abundant species are shaded. Species with constancy of less than 60% are added at the bottom of the table.

Mesic Prairie Constant Species (n=6)		
Species	Constancy (%)	Average Cover (%)
Andropogon gerardii	100.00	24.58
Cirsium flodmanii	100.00	2.10
Galium boreale	100.00	1.70
Liatris spp.*	100.00	2.10
Lobelia spicata	100.00	0.10
Phleum pratense	100.00	8.75
Taraxacum officinale	100.00	0.50
Zigadenus elegans	100.00	1.70
Zizia aptera	100.00	2.50
Achillea millefolium	83.33	0.47
Agoseris glauca	83.33	1.28
Melilotus officinalis	83.33	0.88
Pedicularis canadensis	83.33	1.68
Poa pratensis	83.33	4.17
Schizachyrium scoparium	83.33	1.68
Symphyotrichum ericoides	83.33	1.28
Thalictrum venulosum	83.33	8.33
Zizia aurea	83.33	0.88
Antennaria spp.**	66.67	1.67
Carex sp.	66.67	0.87
Comandra umbellata	66.67	0.47
Dichanthelium spp.***	66.67	0.85
Erigeron strigosus	66.67	0.47
Helianthus maximiliani	66.67	1.27
Hesperostipa spartea	66.67	3.34
Medicago lupulina	66.67	1.27
Prenanthes racemosa	66.67	0.04
Sporobolus heterolepis	66.67	0.47
Trifolium pretense	66.67	0.47
Sorghastrum nutans	50.00	5.42
Bromus inermis	50.00	3.33
Panicum virgatum	33.33	2.92
Spartina pectinata	16.67	2.50

*Includes *L. aspera* and/or *L. ligulistylis*

**Includes species *A. parvifolia* and/or *A. neglecta*

***Includes *D. oligosanthes* and/or *D. leibergii*

Table 2.1. Number of sites and transects under different management regimes.

Management Regime of Sites				
	Number of Sites		Number of Transects	
Management	Inhabited	Formerly Inhabited	Inhabited	Formerly Inhabited
Hayed Late Summer	8	1	39	2
Hayed Midsummer	0	1	0	2
Fall Hay/Periodic Burn	0	2	0	6

Table 2.2. Ten most abundant species of transects sampled at inhabited and formerly inhabited sites (mean cover (%) ± standard error).

Ten Most Abundant Species at Inhabited and Formerly Inhabited Sites			
Inhabited (n=39)		Formerly Inhabited (n=10)	
Species	Mean Cover (%)	Species	Mean Cover (%)
Schizachyrium scoparium	13.73 ± 1.84	*Schizachyrium scoparium*	9.59 ± 2.74
Hesperostipa spartea	11.96 ± 1.18	*Hesperostipa spartea*	5.467 ± 1.31
Amorpha canescens	2.028 ± 0.34	*Andropogon gerardii*	4.78 ± 2.80
Galium boreale	1.70 ± 0.37	*Bromus inermis*	3.98 ± 1.20
Poa pratensis	1.506 ± 0.25	*Galium boreale*	3.85 ± 1.20
Bromus inermis	1.397 ± 0.27	*Poa pratensis*	2.675 ± 1.20
Helianthus pauciflorus	1.33 ± 0.28	*Hesperostipa comata*	2.633 ± 1.10
Echinacea angustifolia	1.19 ± 0.19	*Amorpha canescens*	2.125 ± 0.87
Astragalus crassicarpus	1.14 ± 0.22	*Helianthus pauciflorus*	1.95 ± 0.50
Pediomelum argophyllum	1.10 ± 0.22	*Astragalus adsurgens*	1.58 ± 0.78

Table 2.3. Comparison of vegetation cover of functional groups (mean % cover ± standard error) of transects sampled at inhabited and formerly inhabited sites using Mann-Whitney U test (Mann and Whitney 1947). Functional groups with significant differences in cover (p-values < 0.05) are shaded. EAF = exotic annual forb, EPF= exotic perennial forb, NAF = native annual forb, NPF = native perennial forb, EPG = exotic perennial graminoid, NPG = native perennial graminoid, NPS = native perennial shrub

Comparison of Functional Group Cover Between Inhabited and Formerly Inhabited Sites

Fxn Group	Inhabited Sites (mean cover (%) ± SE)	Formerly Inhabited Sites (mean cover (%) ± SE)	U-statistic	p-value
EAF	0.40 ± 0.06	0.87 ± 0.32	173	0.592
EPF	0.47 ± 0.09	0.62 ± 0.36	260	0.107
NAF	0.17 ± 0.03	0.01 ± 0.01	324	0.001
NPF	13.82 ± 0.74	18.68 ± 1.93	102	0.022
EPG	3.33 ± 0.49	6.65 ± 2.22	131	0.118
NPG	29.55 ± 1.73	24.45 ± 3.87	249.5	0.180
NPS	3.33 ± 0.53	4.6 ± 1.20	160.5	0.399

Table 2.4. Comparison of mean cover (%) (mean ± standard error) of plants used by larvae in their early instar stages as noted by Dana (1991) of transects sampled at inhabited and formerly inhabited sites using the Mann-Whitney U test (Mann and Whitney 1947).

Comparison of Larval Food Plant Cover Between Inhabited and Formerly Inhabited Sites

Larval Food Plants	Inhabited Sites (mean cover (%)±SE)	Formerly Inhabited Sites (mean cover (%)±SE)	U-statistic	p-value
Andropogon gerardii	0.586 ± 0.160	4.775 ± 2.797	176	0.622
Bouteloua curtipendula	0.812 ± 0.343	0.381 ± 0.354	210	0.666
Carex inops	0.009 ± 0.009	0.000 ± 0.000	200	0.649
Carex spp.*	0.227 ± 0.021	0.167 ± 0.053	244.5	0.217
Dichanthelium wilcoxianum	0.133 ± 0.019	0.250 ± 0.100	170.5	0.530
Poa pratensis	1.506 ± 0.279	2.675 ± 1.197	187.5	0.860
Schizachyrium scoparium	13.733 ± 2.060	9.592 ± 2.735	229.5	0.399
Sporobolus heterolepis	0.605 ± 0.236	0.267 ± 0.258	233	0.273
Total Larval Food Plants	17.609 ± 1.911	18.042 ± 4.511	197.5	0.960

*Includes more than three species that could be identified to the genus *Carex*

Table 2.5. Comparison of mean cover (%) (mean ± standard error) of nectar sources as noted by McCabe (1981), Dana (1991) and Swengel and Swengel (1999) of transects sampled at inhabited and formerly inhabited sites using Mann-Whitney U test. Nectar sources with significant differences in cover (p-values < 0.05) are shaded.

Comparison of Nectar Source Cover of Inhabited and Formerly Inhabited Sites				
Nectar Sources	Inhabited Sites (mean cover (%)±SE)	Formerly Inhabited Sites (mean cover (%)±SE)	U-statistic	p-value
Achillea millefolium	0.17 ± 0.02	0.23 ± 0.15	239	0.268
Agoseris glauca	0.27 ± 0.09	0.08 ± 0.06	244	0.170
Asclepias spp.*	0.00 ± 0.00	0.00 ± 0.00	200	0.649
Astragalus sp.	0.02 ± 0.01	0.08 ± 0.02	111	0.006
Astragalus adsurgens	0.14 ± 0.08	1.58 ± 0.78	132	0.016
Astragalus crassicarpus	1.14 ± 0.25	0.03 ± 0.09	271	0.051
Calylophus serrulatus	0.02 ± 0.01	0.03 ± 0.01	171.5	0.414
Echinacea angustifolia	1.19 ± 0.21	0.97 ± 0.17	175	0.628
Erigeron strigosus	0.00 ± 0.00	0.00 ± 0.00	205	0.492
Gaillardia aristata	0.02 ± 0.01	0.07 ± 0.04	167	0.332
Galium boreale	1.70 ± 0.42	3.85 ± 1.20	101	0.020
Lactuca tatarica	0.20 ± 0.05	0.01 ± 0.01	319	0.001
Lilium philadelphicum	0.00 ± 0.00	0.00 ± 0.00	200	0.649
Medicago sativa	0.00 ± 0.00	0.50 ± 0.33	156	0.005
Oxytropis lambertii	0.04 ± 0.02	0.00 ± 0.00	210	0.387
Penstemon gracilis	0.02 ± 0.01	0.00 ± 0.00	240	0.101
Ratibida columnifera	0.04 ± 0.01	0.03 ± 0.02	210.5	0.631
Trifolium pratense	0.02 ± 0.01	0.00 ± 0.00	205	0.492
Verbena stricta	0.00 ± 0.00	0.00 ± 0.00	200	0.649
Zigadenus elegans	0.08 ± 0.04	0.02 ± 0.02	229.5	0.263
Total Nectar Source	5.07 ± 0.58	7.63 ± 1.10	115.5	0.050

* Includes *A. speciosa* and/or *A. syriaca*

Table 2.6. Correlations between main matrix species and NMS axes of the ordination of transect vegetation composition. The r values are reported for all species. All species included in the table have Pearson correlation coefficients with p-value <0.005 (Fisher and Yates 1963).

Species Correlations with NMS Axes

Axis 1

species	r	r-squared	tau
Hesperostipa spartea	0.68	0.46	0.32
Rosa arkansana	0.63	0.40	0.46
Oligoneuron rigidum	0.61	0.37	0.55
Viola pedatifida	0.61	0.37	0.28
Dichanthelium leibergii	0.54	0.29	0.46
Anemone cylindrica	0.51	0.26	0.30
Amorpha canescens	0.48	0.23	0.28
Symphoricarpos occidentalis	0.45	0.21	0.36
Galium boreale	0.43	0.19	0.25
Astragalus sp.	0.43	0.18	0.39
Bouteloua curtipendula	0.42	0.18	0.33
Dalea purpurea	0.41	0.17	0.30
Liatris punctata	-0.85	0.73	-0.59
Cerastium arvense	-0.76	0.57	-0.56
Koeleria macrantha	-0.63	0.39	-0.48
Gaillardia aristata	-0.61	0.37	-0.43
Hesperostipa comata	-0.57	0.33	-0.49
Bouteloua gracilis	-0.57	0.32	-0.45
Lomatium spp.*	-0.56	0.31	-0.41
Artemisia frigida	-0.54	0.29	-0.43
Gaura coccinea	-0.52	0.27	-0.36
Allium stellatum	-0.52	0.27	-0.42
Castilleja sessiliflora	-0.43	0.18	-0.37
Astragalus adsurgens	-0.42	0.18	-0.35
Hedeoma hispida	-0.42	0.18	-0.33
Lithospermum incisum	-0.41	0.17	-0.31
Heterotheca villosa	-0.40	0.16	-0.31

*Includes *L. foeniculaceum* and/or *L. orientale*

Axis 2

species	r	r-squared	tau
Antennaria parvifolia	0.68	0.47	0.56
Viola pedatifida	0.53	0.29	0.42
Achillea millefolium	0.46	0.21	0.29
Taraxacum officinale	0.44	0.19	0.35

Dichanthelium wilcoxianum	-0.59	0.35	-0.43
Artemisia ludoviciana	-0.59	0.34	-0.37
Ambrosia psilostachya	-0.55	0.30	-0.45
Helianthus pauciflorus	-0.46	0.21	-0.38
Sporobolus compositus	-0.43	0.18	-0.34
Monarda fistulosa	-0.41	0.17	-0.36

Table 2.7. Mean cover (%) and frequency (%) of significant indicator species (p-value < 0.05) of inhabited and formerly inhabited sites for transect vegetation composition data. Indicator species values are shaded in column of associated group. Inhabited and formerly inhabited transects were sampled at sites where Dakota skippers were considered present or exitrpated, respectively.

Indicator Species at Inhabited and Formerly Inhabited Sites					
	Mean Cover (%)		Frequency (%)		
Group	Inhabited	Formerly Inhabited	Inhabited	Formerly Inhabited	p-value
number of transects/group	39	10	39	10	
Lactuca tatarica	0.20	0.01	69.23	10.00	0.0046
Hesperostipa spartea	11.96	5.47	94.87	90.00	0.0122
Taraxacum officinale	0.42	0.10	84.62	60.00	0.0156
Polygala verticillata	0.05	0.00	43.59	0.00	0.0326
Zizia aptera	0.17	0.00	43.59	0.00	0.033
Astragalus crassicarpus	1.14	0.21	64.10	40.00	0.0498
Monarda fistulosa	0.00	0.38	0.00	50.00	0.0004
Artemisia ludoviciana	0.06	0.77	28.21	70.00	0.0008
Sporobolus compositus	0.00	0.08	0.00	40.00	0.0008
Solidago canadensis	0.02	1.48	7.69	50.00	0.0026
Onosmodium bejariense	0.36	0.03	0.00	30.00	0.006
Astragalus sp.	0.02	0.08	15.39	60.00	0.007
Astragalus adsurgens	0.14	1.58	10.26	40.00	0.0106
Physalis virginiana	0.08	0.15	51.28	90.00	0.018
Symphyotrichum ericoides	0.22	0.41	82.05	100.00	0.0242
Lithospermum canescens	0.07	0.20	43.59	70.00	0.0306
Oligoneuron rigidum	0.00	0.68	48.72	90.00	0.0314
Galium boreale	1.70	3.85	82.05	100.00	0.0316
Comandra umbellata	0.36	0.68	92.31	100.00	0.0318
Ambrosia psilostachya	0.06	0.09	20.51	60.00	0.0468

Table 2.8. Correlations between the main matrix species and the NMS axes of the site ordination. All species included in the table have Pearson correlation coefficients with p-value <0.05 (Fisher and Yates 1963).

Species Correlations with NMS Axes			
Axis 1			
species	r	r-squared	tau
Rosa arkansana	0.88	0.77	0.60
Oligoneuron rigidum	0.77	0.60	0.60
Dichanthelium leibergii	0.76	0.57	0.66
Symphoricarpos occidentalis	0.75	0.56	0.39
Sisyrinchium monantum	0.75	0.55	0.63
Anemone cylindrica	0.73	0.54	0.61
Monarda fistulosa	0.73	0.53	0.56
Astragalus sp.	0.72	0.51	0.67
Onosmodium bejariense	0.71	0.50	0.51
Anemone canadensis	0.67	0.44	0.64
Artemisia ludoviciana	0.66	0.44	0.35
Sporobolus compositus	0.66	0.44	0.51
Solidago canadensis	0.66	0.44	0.41
Dalea purpurea	0.62	0.38	0.35
Bouteloua curtipendula	0.62	0.38	0.33
Amorpha canescens	0.60	0.37	0.46
Koeleria macrantha	-0.93	0.87	-0.70
Gaillardia aristata	-0.85	0.73	-0.74
Bouteloua gracilis	-0.83	0.69	-0.71
Cerastium arvense	-0.83	0.69	-0.67
Liatris punctata	-0.83	0.68	-0.64
Artemisia frigida	-0.81	0.66	-0.67
Pediomelum esculentum	-0.78	0.61	-0.70
Heterotheca villosa	-0.72	0.52	-0.61
Astragalus adsurgens	-0.63	0.40	-0.52
Nassella viridula	-0.63	0.40	-0.43
Tragopogon dubius	-0.61	0.38	-0.46
Allium stellatum	-0.59	0.35	-0.56

Axis 2			
species	R	r-squared	Tau
Heuchera richardsonii	0.89	0.80	0.55
Phleum pratense	0.83	0.69	0.71
Zizia aptera	0.80	0.64	0.60
Hesperostipa spartea	0.76	0.58	0.58
Taraxacum officinale	0.65	0.43	0.53

Arabis hirsuta	0.65	0.43	0.56
Delphinium carolinianum	0.65	0.42	0.56
Sorghastrum nutans	0.64	0.41	0.67
Carex meadii	0.64	0.40	0.48
Astragalus crassicarpus	0.63	0.40	0.41
Avenula hookeri	0.63	0.4	0.63
Zigadenus elegans	0.62	0.39	0.43
Antennaria parvifolia	0.61	0.37	0.4
Pediomelum argophyllum	0.59	0.35	0.42
Thalictrum venulosum	0.58	0.34	0.33
Packera plattensis	-0.58	0.33	-0.48
Physalis virginiana	-0.58	0.33	-0.5

Axis 3

species	R	r-squared	Tau
Lithospermum incisum	0.84	0.71	0.68
Ambrosia psilostachya	0.76	0.58	0.67
Polygala alba	0.68	0.46	0.53
Penstemon gracilis	0.66	0.44	0.57
Arabis hirsuta	0.59	0.35	0.43
Symphyotrichum oblongifolium	0.59	0.35	0.49
Allium stellatum	0.58	0.34	0.48
Thalictrum venulosum	-0.60	0.36	-0.47

Table 2.9. Correlations of secondary matrix with synthesized NMS axes of the ordination of vegetation composition at the site level. The first four variables were recorded at each transect and then averaged at the site level. None of the correlation coefficients were significant ($p < 0.05$) (Fisher and Yates 1963).

Secondary Variable Correlations with NMS Axes									
	Axis 1			Axis 2			Axis 3		
Variables	r	r-squared	tau	r	r-squared	tau	r	r-squared	tau
Transect									
Litter Depth	0.32	0.10	0.05	-0.11	0.01	-0.02	0.33	0.11	0.20
Litter Cover	-0.52	0.27	-0.20	0.34	0.11	0.11	0.49	0.24	0.53
Bare Ground	0.49	0.24	0.08	-0.34	0.12	-0.17	-0.06	0.00	-0.05
Rock	-0.34	0.12	-0.40	0.49	0.24	0.16	0.26	0.07	0.30
Site									
Site Size	0.14	0.02	0.09	0.41	0.16	0.46	0.21	0.04	0.12

Table 2.10. The ten nectar-producing species with the highest density of flowering stems for transects sampled at inhabited and formerly inhabited sites (# flowering stems/m^2 ± standard error).

Ten Most Abundant Flowering Species			
Inhabited Transects		Formerly Inhabited	
Species	Mean Density (stems/m^2)	Species	Mean Density (stems/m^2)
Echinacea angustifolia	0.42 ± 0.09	*Astragalus adsurgens*	1.86 ± 0.93
Melilotus officinalis	0.31 ± 0.15	*Melilotus officinalis*	1.79 ± 0.91
Astragalus adsurgens	0.18 ± 0.86	*Galium boreale*	1.52 ± 1.03
Pediomelum argophyllum	0.15 ± 0.04	*Echinacea angustifolia*	0.36 ± 0.10
Polygala alba	0.06 ± 0.04	*Medicago sativa*	0.23 ± 0.14
Achillea millefolium	0.05 ± 0.01	*Medicago lupulina*	0.20 ± 0.14
Erigeron strigosus	0.03 ± 0.01	*Pediomelum argophyllum*	0.13 ± 0.05
Linum rigidum	0.03 ± 0.01	*Achillea millefolium*	0.11 ± 0.08
Galium boreale	0.03 ± 0.02	*Symphoricarpos occidentalis*	0.08 ± 0.08
Agoseris glauca	0.03 ± 0.01	*Calylophus serrulatus*	0.08 ± 0.03

Table 2.11. Comparison of density of flowering stems of nectar sources (mean # stems/m^2 ± standard error) as noted by McCabe (1981), Dana (1991), and Swengel and Swengel (1999) for transects sampled at inhabited and formerly inhabited sites using Mann-Whitney U test (Mann and Whitney 1947). Nectar sources with significant differences in cover (p-values < 0.05) are shaded. Long dashes (—) indicate species were absent from group.

Comparison of Flowering Nectar Sources at Inhabited and Formerly Inhabited Sites				
Nectar Sources	Inhabited Sites (mean # stems/m^2±SE)	Formerly Inhabited Sites (mean # stems/m^2±SE)	U statistic	p-value
Achillea millefolium	0.047 ± 0.027	0.109 ± 0.083	221.5	0.513
Agoseris glauca	0.027 ± 0.010	0.000 ± 0.000	275	0.018
Astragalus adsurgens	0.179 ± 0.086	1.856 ± 0.925	169	0.478
Astragalus agrestis	—	0.001 ± 0.001	175.5	0.054
Calylophus serrulatus	0.022 ± 0.006	0.079 ± 0.030	106.5	0.022
Echinacea angustifolia	0.424 ± 0.092	0.356 ± 0.099	181	0.738
Erigeron strigosus	0.033 ± 0.006	0.009 ± 0.002	278	0.036
Gaillardia aristata	0.003 ± 0.002	0.014 ± 0.009	155.5	0.118
Galium boreale	0.030 ± 0.017	1.522 ± 1.029	81	0.002
Heterotheca villosa	0.008 ± 0.003	0.028 ± 0.027	201	0.852
Lilium philadelphicum	0.000 ± 0.000	—	200	0.649
Medicago sativa	0.004 ± 0.003	0.229 ± 0.141	124.5	0.002
Oxytropis lambertii	0.001 ± 0.001	0.006 ± 0.006	184.5	0.551
Penstemon gracilis	0.016 ± 0.004	0.007 ± 0.004	230	0.336
Ratibida columnifera	0.001 ± 0.001	0.000 ± 0.000	210	0.387
Trifolium pratense	0.001 ± 0.001	—	205	0.492
Zigadenus elegans	0.012 ± 0.006	0.074 ± 0.073	180.5	0.568
Total Nectar Source	0.807 ± 0.137	4.29 ± 1.24	79	0.004

Table 2.12. Correlations between main matrix species and NMS axes of the ordination of flowering stem data. All species included in the table have Pearson correlation coefficients with p-value <0.005 (Fisher and Yates 1963).

Species Correlations with NMS Axes			
Axis 1			
species	r	r-squared	tau
Pediomelum argophyllum	0.64	0.41	0.57
Sisyrinchium montanum	0.43	0.18	0.27
Galium boreale	0.42	0.18	0.17
Heterotheca villosa	-0.52	0.27	-0.46
Axis 2			
species	R	r-squared	Tau
Melilotus officinalis	0.61	0.37	0.44
Gaillardia aristata	0.49	0.24	0.40
Medicago sativa	0.48	0.23	0.40
Gaura coccinea	0.42	0.18	0.30
Tragopogon dubius	0.42	0.18	0.30
Echinacea angustifolia	0.41	0.17	0.24
Potentialla pensylvanica	0.41	0.17	0.33
Agoseris glauca	-0.63	0.39	-0.56
Erigeron strigosus	-0.52	0.27	-0.44

Table 2.13. Mean # of stems per transect and frequency (%) of significant indicator species (p-value<0.05) of flowering species for transects at inhabited and formerly inhabited sites. Indicator species values are shaded in column of associated group. Inhabited and formerly inhabited transects were sampled at sites where Dakota skippers were considered present and extirpated, respectively. ISA = Indicator Species Analysis

Flowering Species Indicator Species					
	Mean # Stems		Frequency (%)		
group	Inhabited	Formerly Inhabited	Inhabited	Formerly Inhabited	ISA p-value
# of transects/group	39	10	39	10	
Agoseris glauca	2.67	0	41.03	0	0.0374
Galium boreale	3.00	152.2	41.03	80	0.0022
Medicago sativa	0.38	22.9	5.13	40	0.0028
Potentilla pensylvanica	0.10	0.9	10.26	50	0.0032
Lithospermum canescens	0.05	0.6	5.13	40	0.0040
Calylophus serrulatus	2.18	7.9	48.72	90	0.0072
Melilotus officinalis	30.69	178.5	53.85	80	0.0336
Symphoricarpos occidentalis	0.03	8.2	2.56	20	0.0364
Sisyrinchium montanum	0.00	0.2	0.00	20	0.0386
Glycyrrhiza lepidota	0.00	0.6	0.00	20	0.0440
Medicago lupulina	0.74	20.3	12.82	30	0.0456

FIGURES

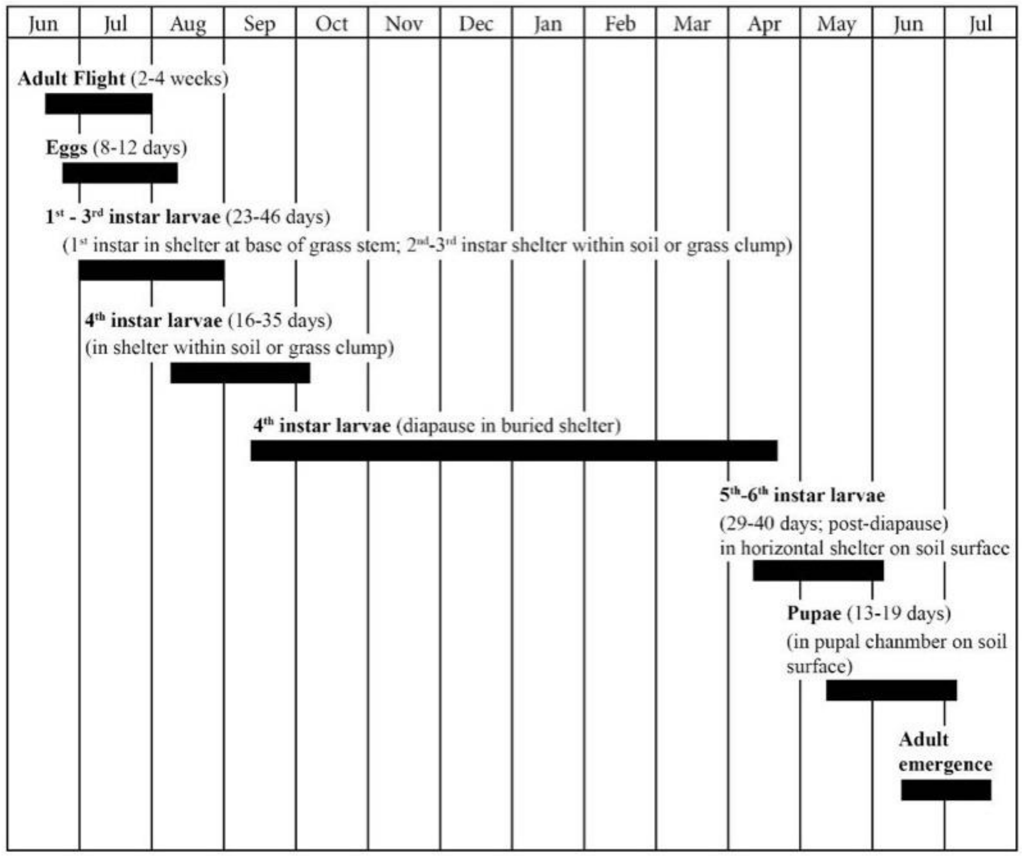

Figure 1.1. Timeline of Dakota skipper life cycle stages (reproduced from Environment Canada (2007) and Dana (1991)).

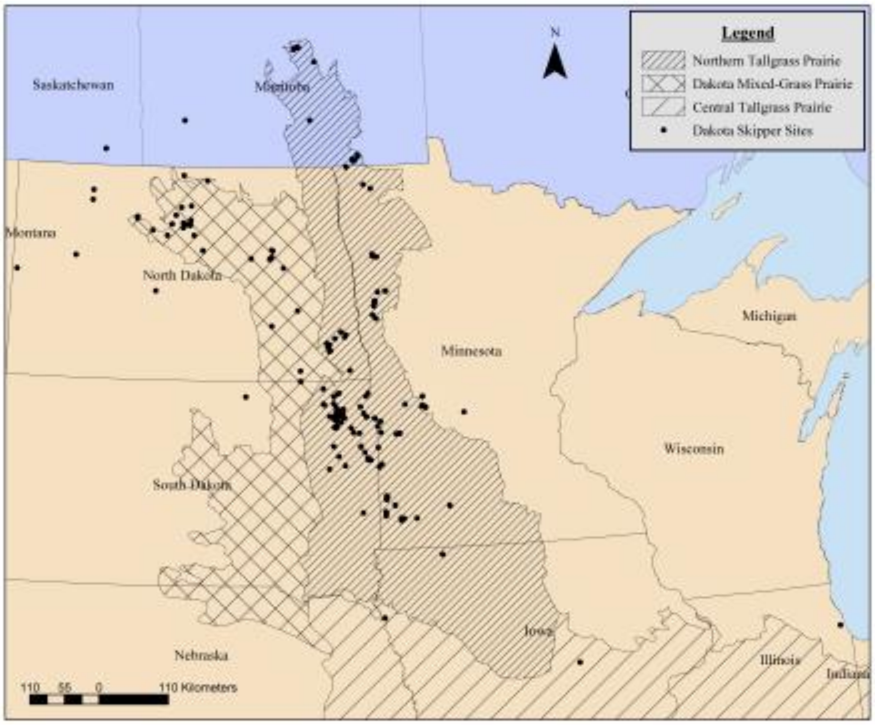

Figure 1.2. Dakota skipper sites (including formerly inhabited sites) shown by black dots superimposed on top of TNC ecoregions (Reproduced from Cochrane and Delphey 2002).

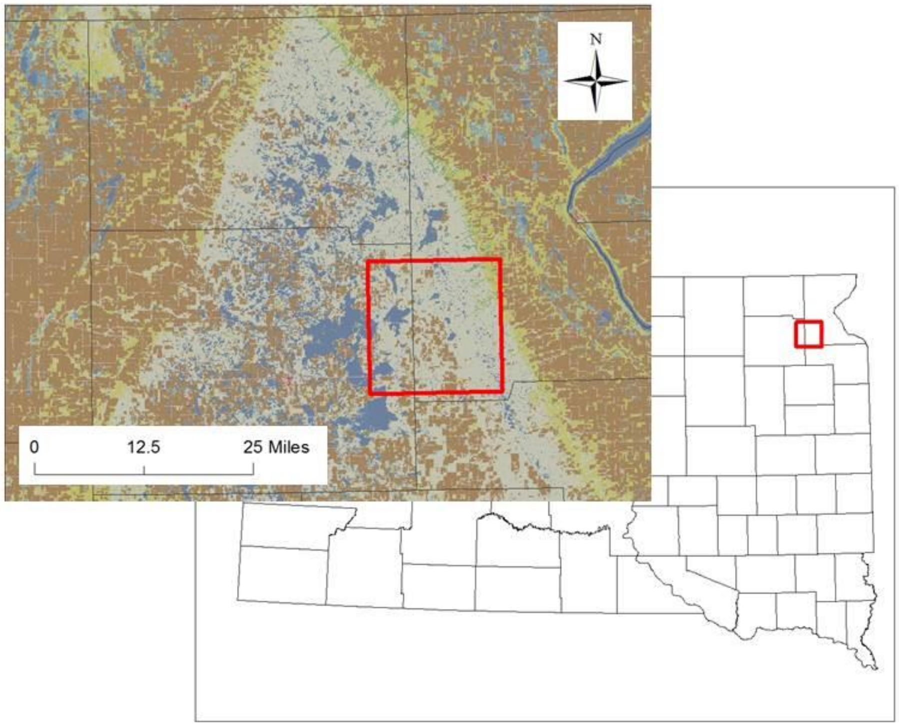

Figure 1.3. Map showing location of study area in NE South Dakota and location on the SD Prairie Coteau, defined in the inset by using the 2006 National Land Cover Dataset (Fry et al. 2011).

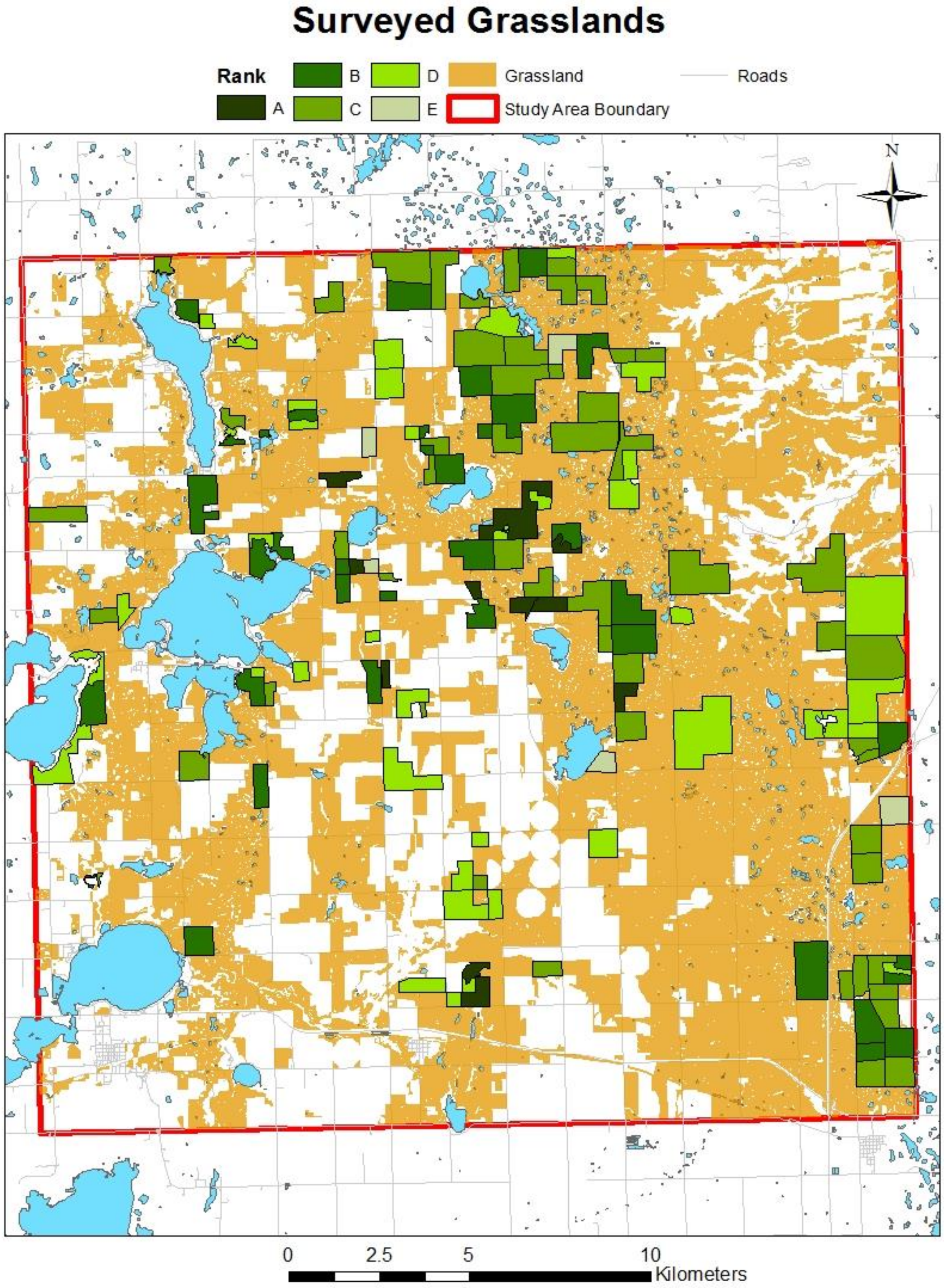

Figure 1.4. Map of study area showing the grasslands layer, which delineates all grasslands including disturbed and undisturbed sod, and all surveyed grasslands and their condition.

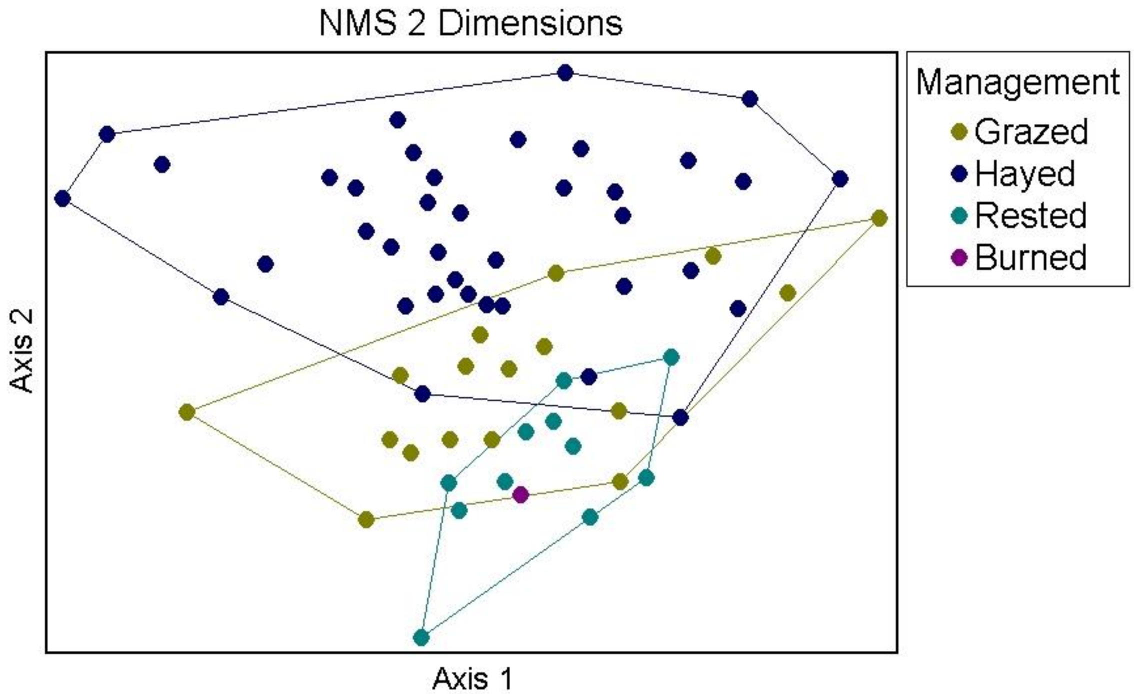

Figure 1.5. NMS ordination of relevé plots with overlay of different management regimes. Each point represents an individual plot. Each symbol represents a different management regime. Convex hulls encircle each group of management regimes. Axis 1 represented a soil moisture gradient, decreasing from left to right. Axis 2 was associated with management regime.

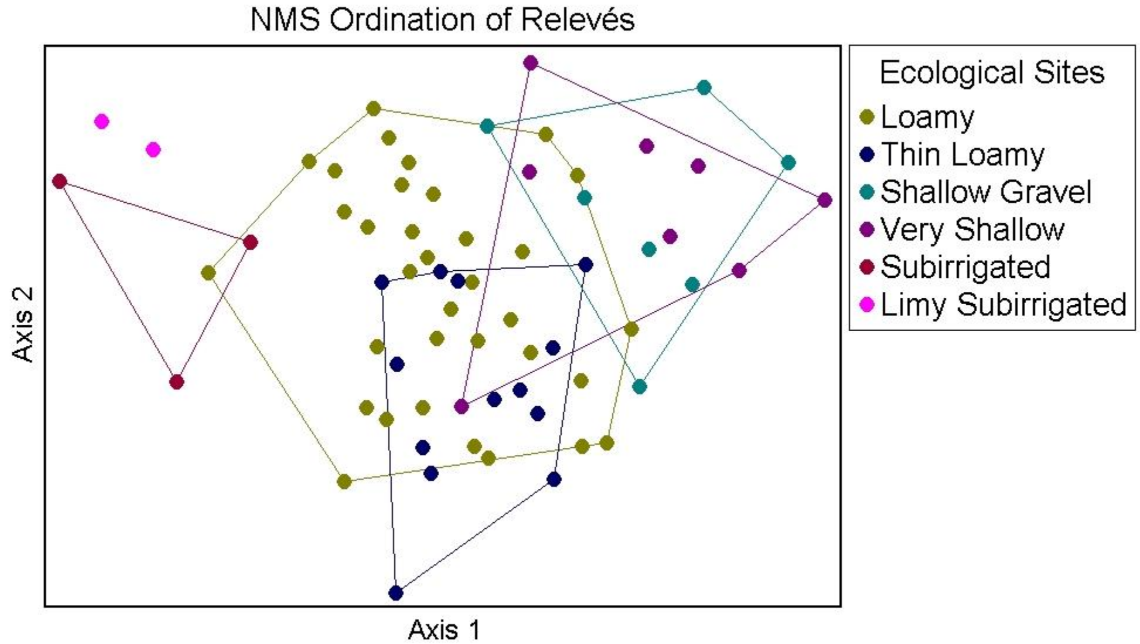

Figure 1.6. NMS ordination of relevé plots with overlay of ecological sites. Each point represents an individual plot. Each color represents a different ecological site. Convex hulls are drawn around the boundaries of each group of ecological sites. Axis 1 represents a soil moisture gradient, decreasing from left to right. Axis 2 is associated with management regime (hayed plots at the top, grazed plots in the middle, rested plots at the bottom).

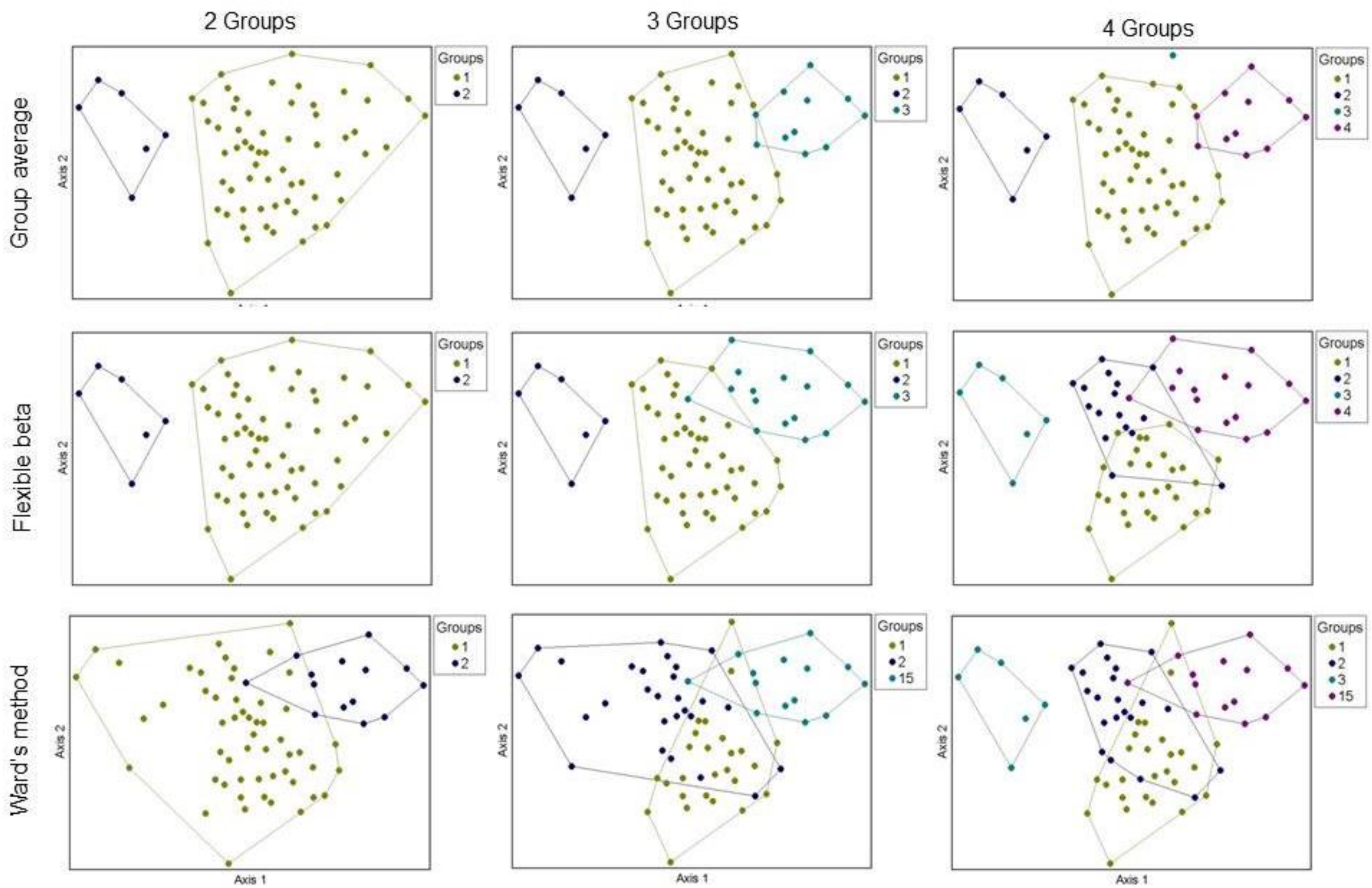

Figure 1.7. Overlay of resulting clusters from group average, flexible beta (β = -.025), and Ward's methods at the 2, 3 and 4 group level on top of the final NMS ordination configuration.

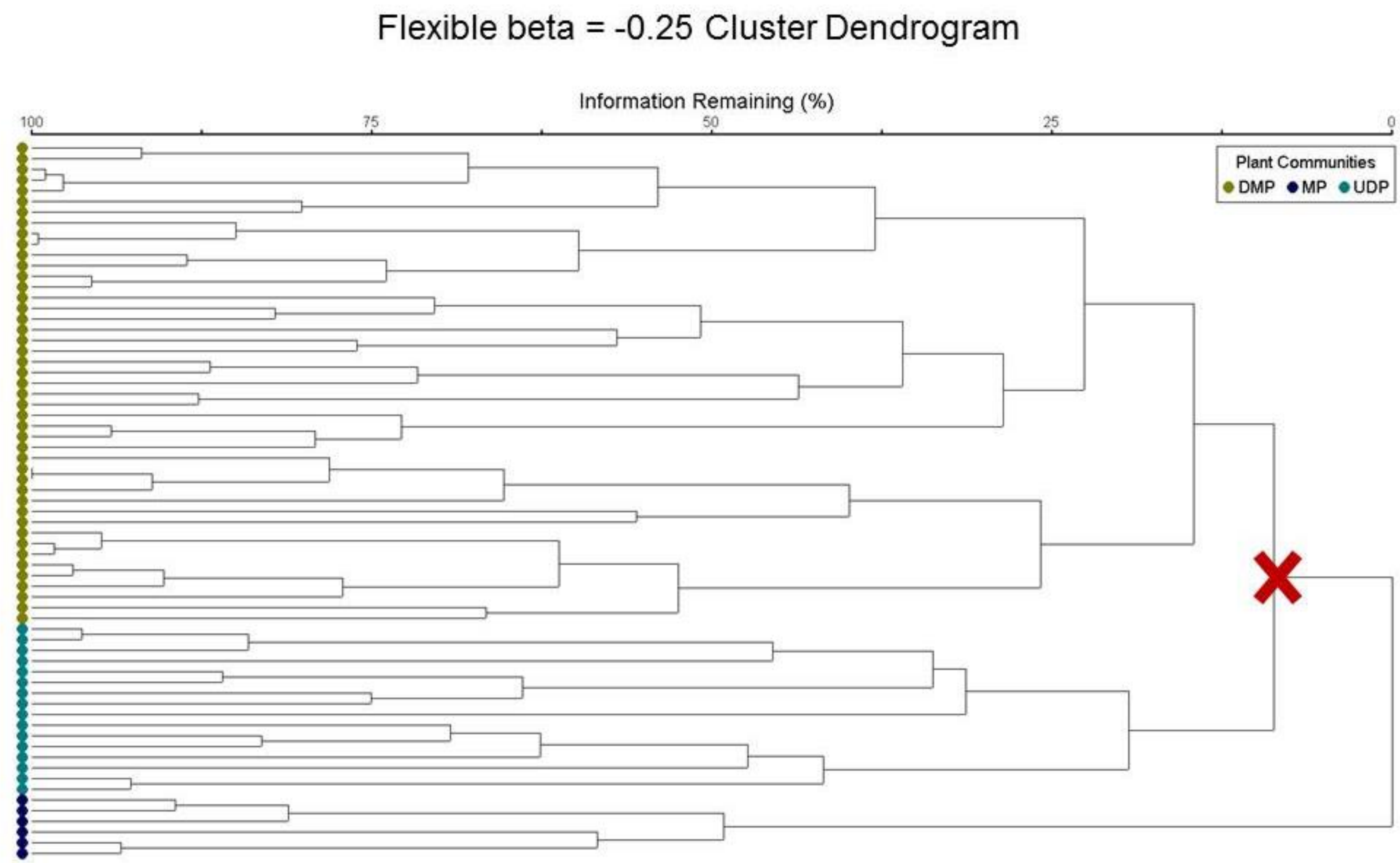

Figure 1.8. Dendrogram produced by flexible beta (β = -.025) cluster method using Sørenson distance. The red X indicates where the dendrogram was pruned to produce the three plant communities, DMP = Dry-Mesic Prairie, MP = Mesic Prairie, UDP = Upland Dry Prairie.

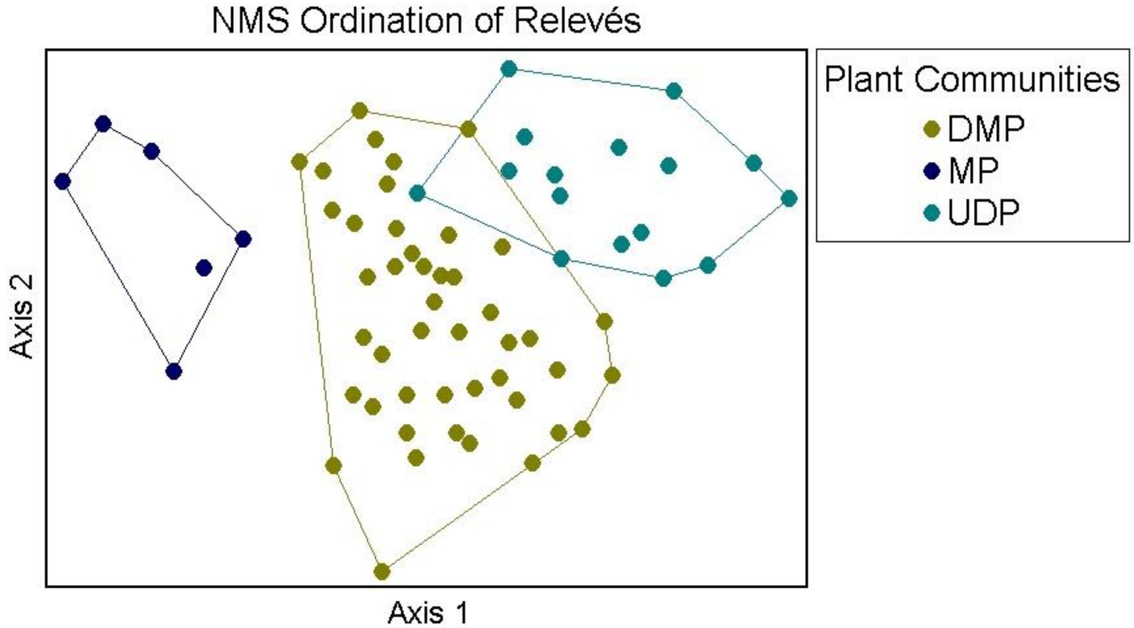

Figure 1.9. NMS ordination of relevé plots overlaid with the groups determined by cluster analysis. Each point represents an individual plot. Each color represents a different plant community. Convex hulls are drawn around the boundary of each group. Axis 1 represents a soil moisture gradient decreasing from left to right. Axis 2 is associated with management regime and date of sampling (early season to late season from bottom to top). DMP = Dry-Mesic Prairie, MP= Mesic Prairie, UDP = Upland Dry Prairie

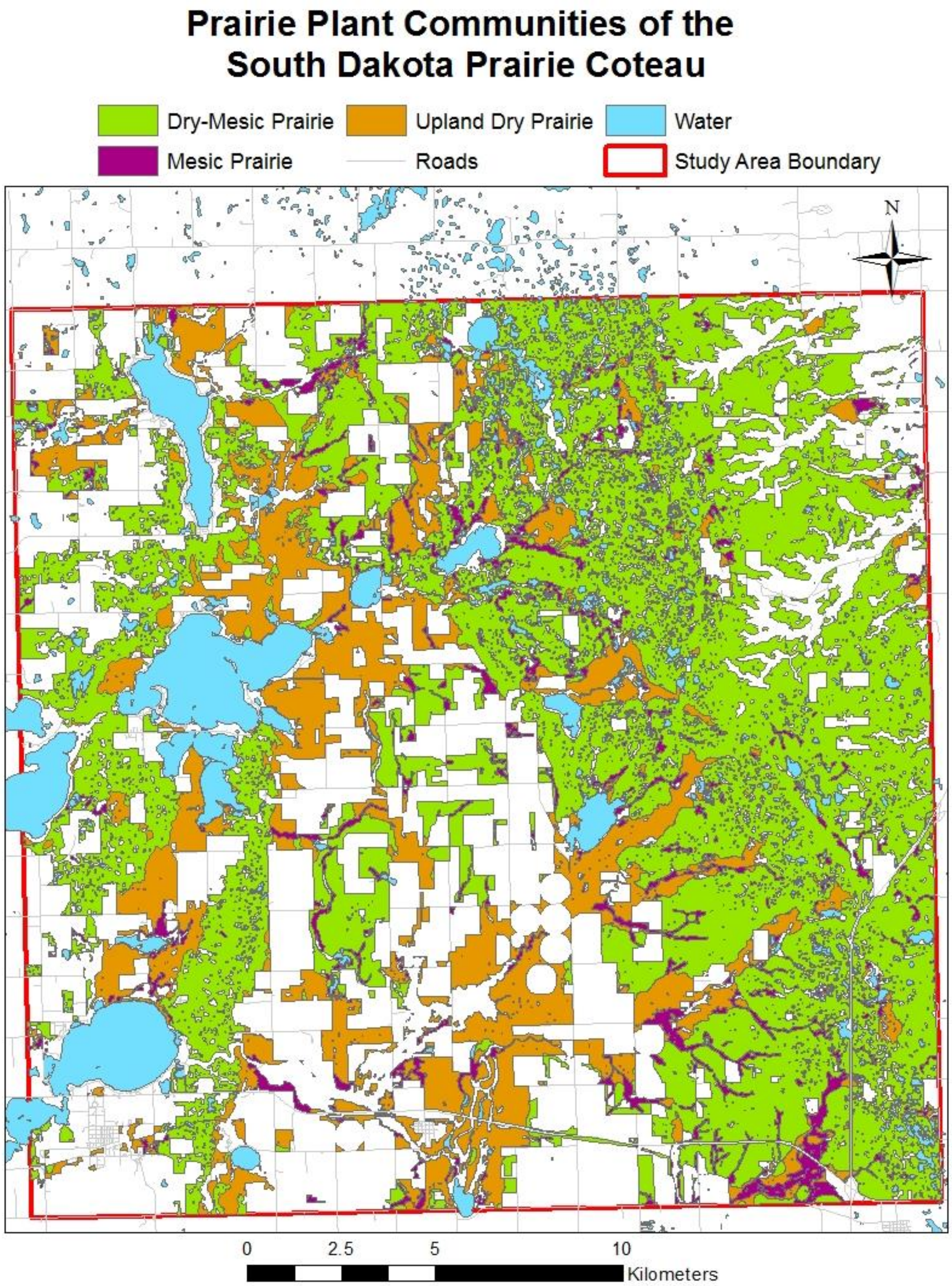

Figure 1.10. Map of prairie plant community types within the study area.

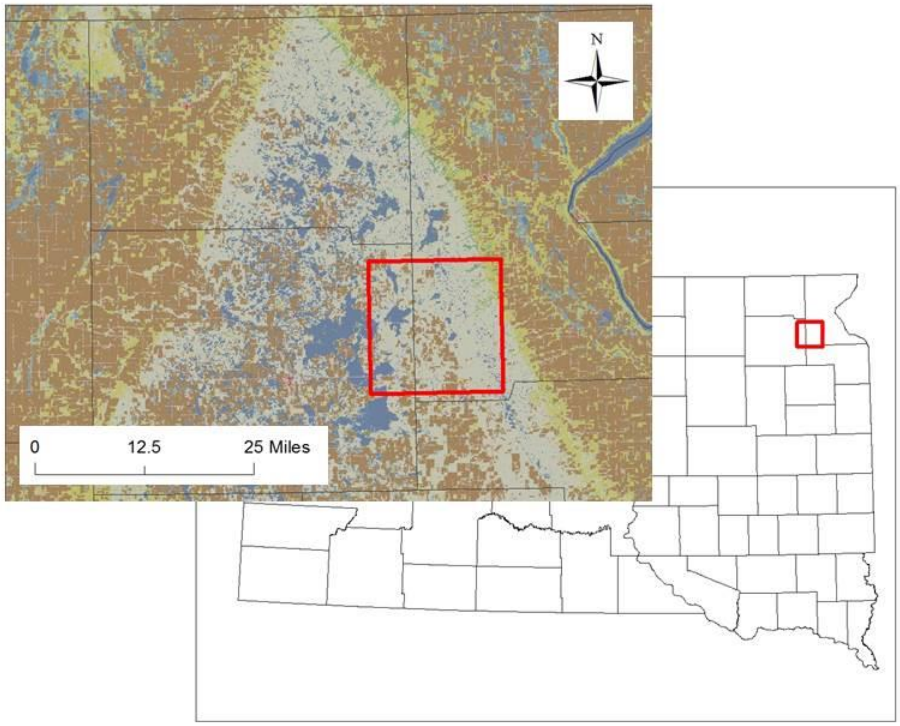

Figure 2.1. Map showing location of study area in NE South Dakota and location on the SD Prairie Coteau, defined in the inset by using the 2006 National Land Cover Dataset (Fry et al. 2011).

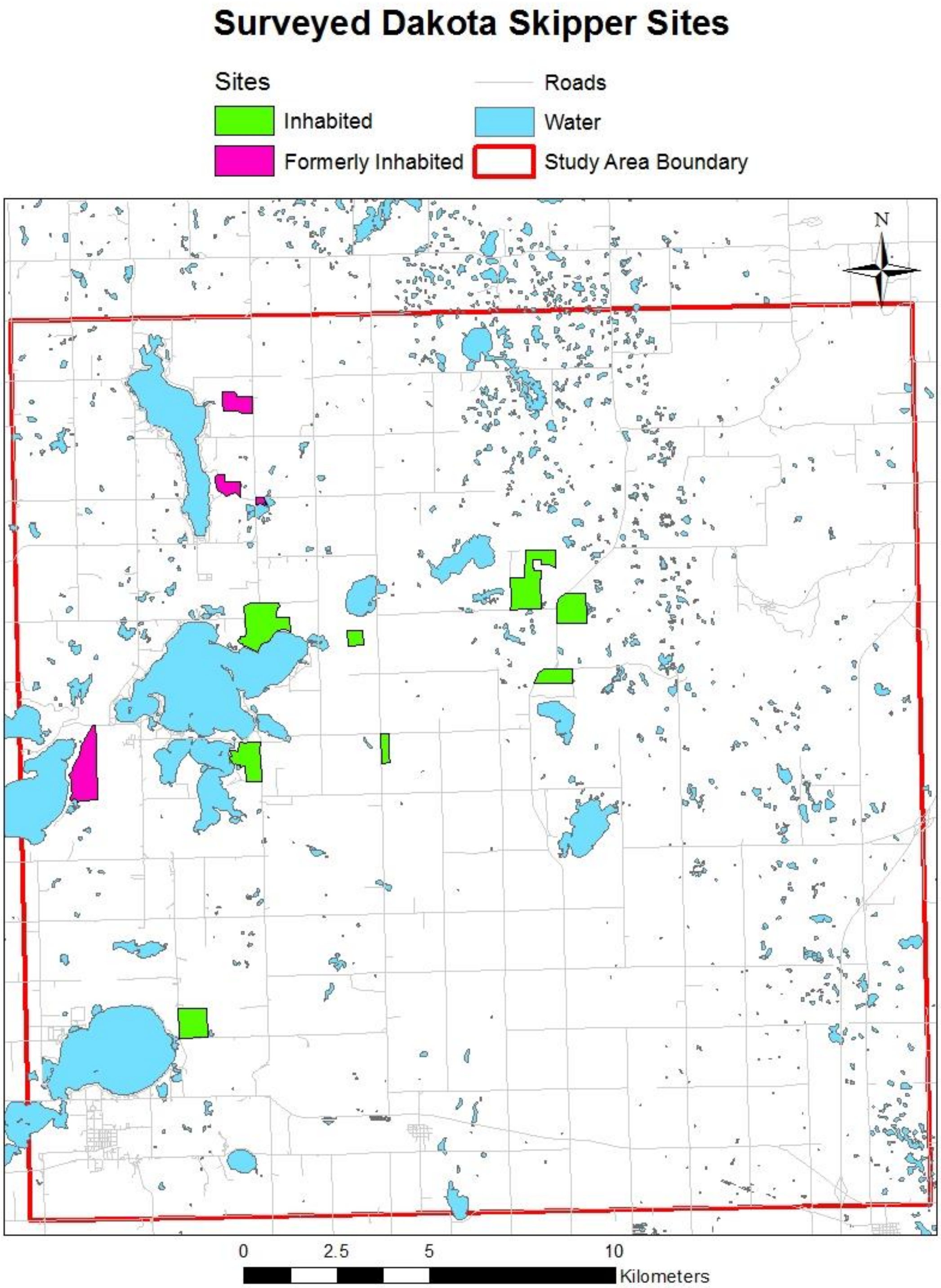

Figure 2.2. Map showing locations of inhabited and formerly inhabited sites in the study area where transect sampling was performed.

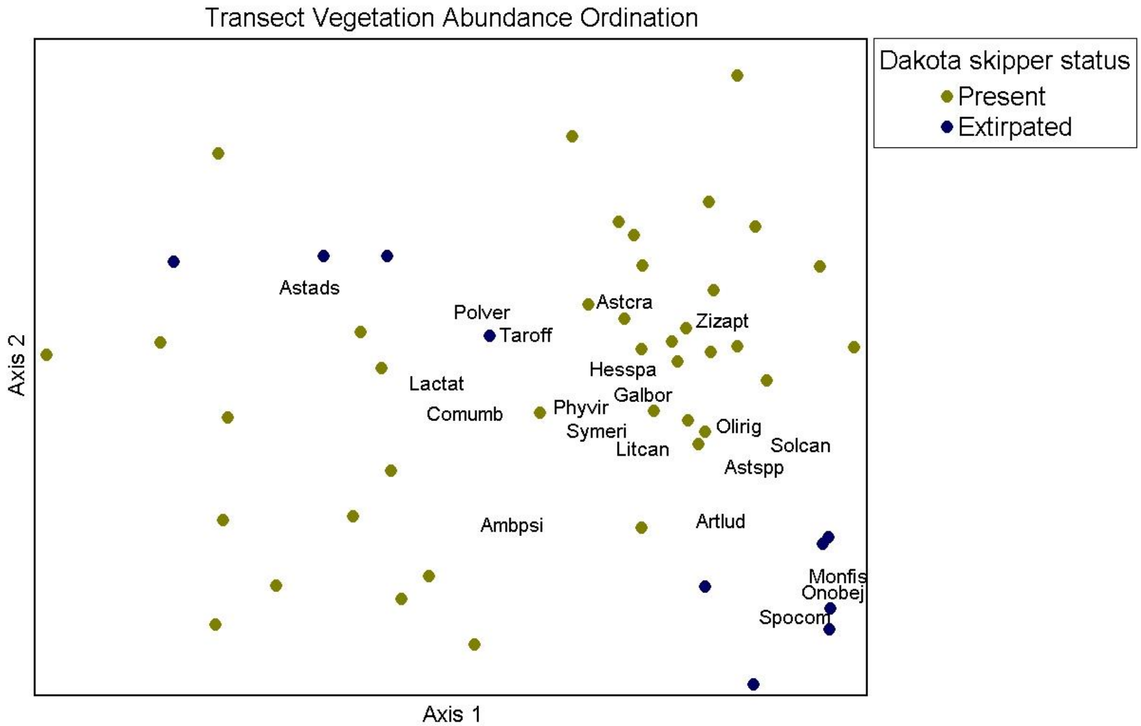

Figure 2.3. NMS ordination of transects using vegetation cover data with the status of the Dakota skipper at each site where transect was sampled indicated by color. Each point represents an individual transect. Axis 1 represents a soil moisture gradient decreasing from left to right. Indicator species with p-values < 0.05 for each group are shown. Ambpsi = *Ambrosia psilostachya*, Artlud = *Artemisia ludoviciana*, Astads = *Astragalus adsurgens*, Astcra = *Astragalus crassicarpus*, Astspp = *Astragalus* sp., Comumb = *Comandra umbellata*, Galbor = *Galium boreale*, Hesspa = *Hesperostipa spartea*, Lactat = *Lactuca tatarica*, Litcan = *Lithospermum canescens*, Monfis = *Monarda fistulosa*, Olirig = *Oligoneuron rigidum*, Onobej = *Onosmodium bejariense*, Phyvir = *Physalis virginiana*, Polver = *Polygala verticillata*, Solcan = *Solidago canadensis*, Spocom = Sporobolus compositus, Symeri = *Symphyotrichum ericoides*, Taroff = *Taraxacum officinale*, Zizapt = *Zizia aptera*.

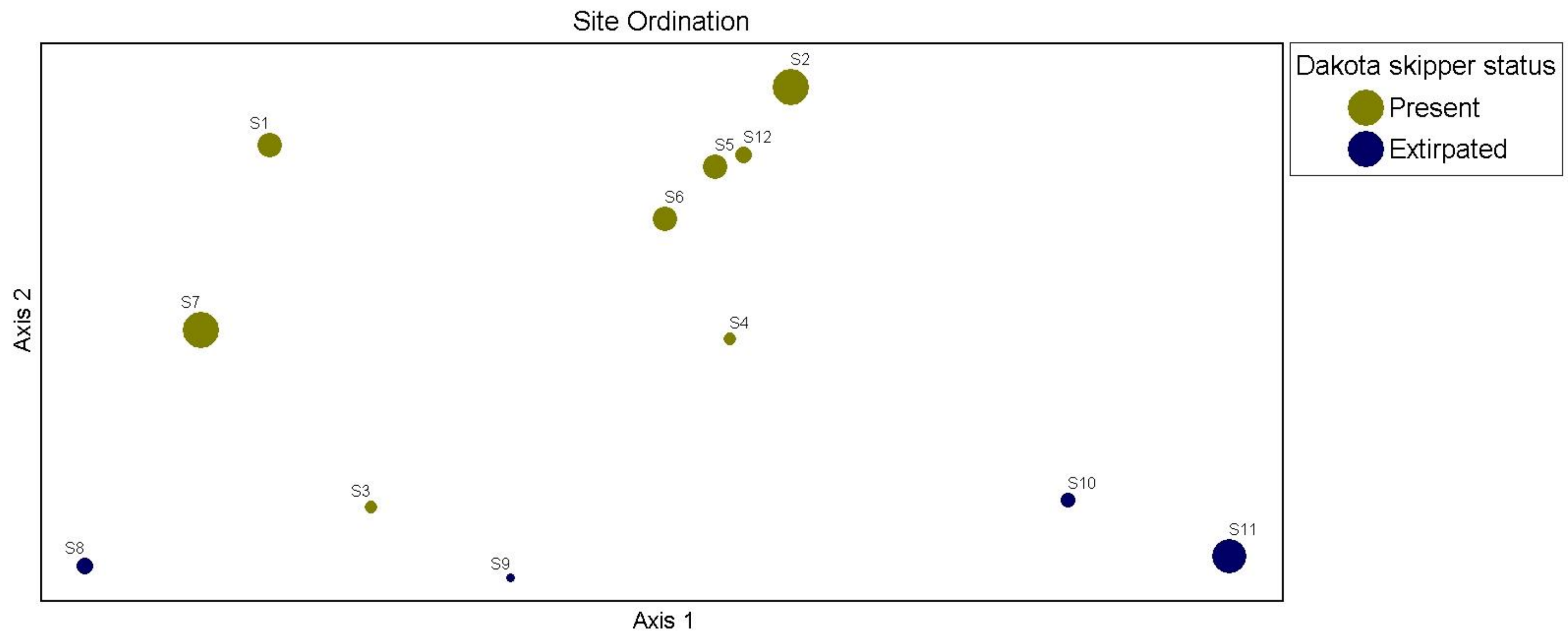

Figure 2.4. NMS ordination of vegetation abundance averaged to the site level with inhabited sites shown in green and formerly inhabited sites shown in dark blue. The size of each site is represented by the size of the circle, ranging from 4.8 ha (size of the smallest site) to 108.5 ha (size of the largest site). S1 = Goodboy Prairie, S2 = Oak Island Prairie, S3 = East Enemy Swim Prairie, S4 = Hayes Prairie, S5 = Scarlet Fawn Prairie, S6 = East Bluedog Lake Prairie, S7 = North Enemy Swim Lake, S8 = Chekapa Creek Ridge, S9 = Wakidmanwin Prairie, S10 = East Pickeral Lake, S11 = Waubay National Wildlife Refuge, S12 = North Owl Lake Prairie

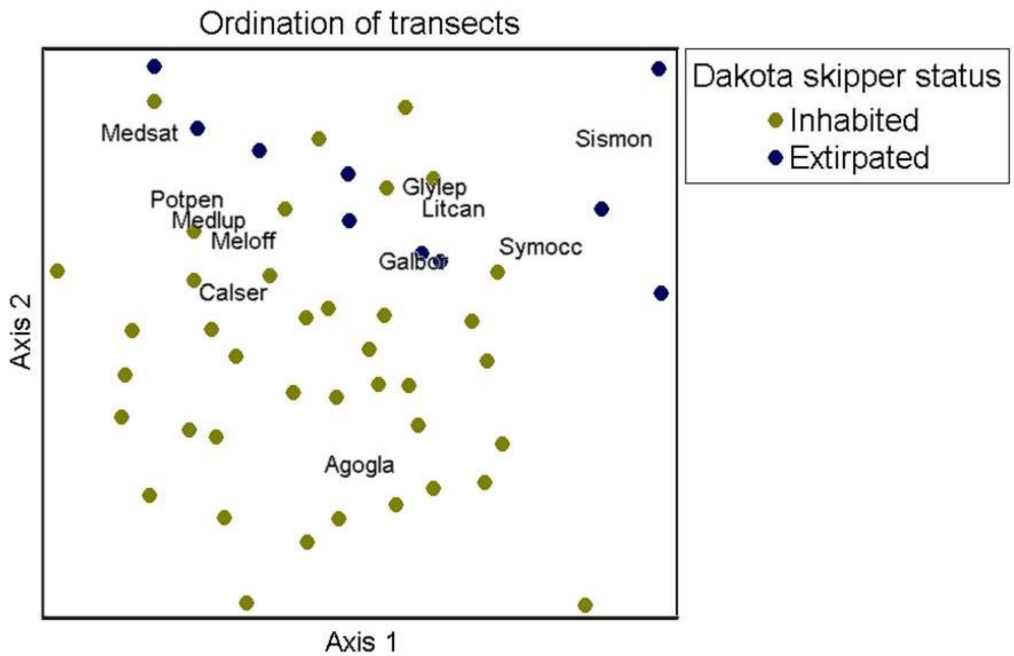

Figure 2.5. NMS ordination of transects using flower survey data with the status of the Dakota skipper at each site where transect was sampled indicated by color. Each point represents an individual transect. Indicator species with p-values < 0.05 for each group are shown. Agogla = *Agoseris glauca*, Calser = *Calylophus serrulatus*, Galbor = *Galium boreale*, Glylep = *Glycyrrhiza lepidota*, Litcan = *Lithospermum canescens*, Medlup = *Medicago lupulina*, Medsat = *Medicago sativa*, Meloff = *Melilotus officinalis*, Potpen = *Potentilla pensylvanica*, Sismon = *Sisyrinchium montanum*, Symocc = *Symphoricarpos occidentalis*,

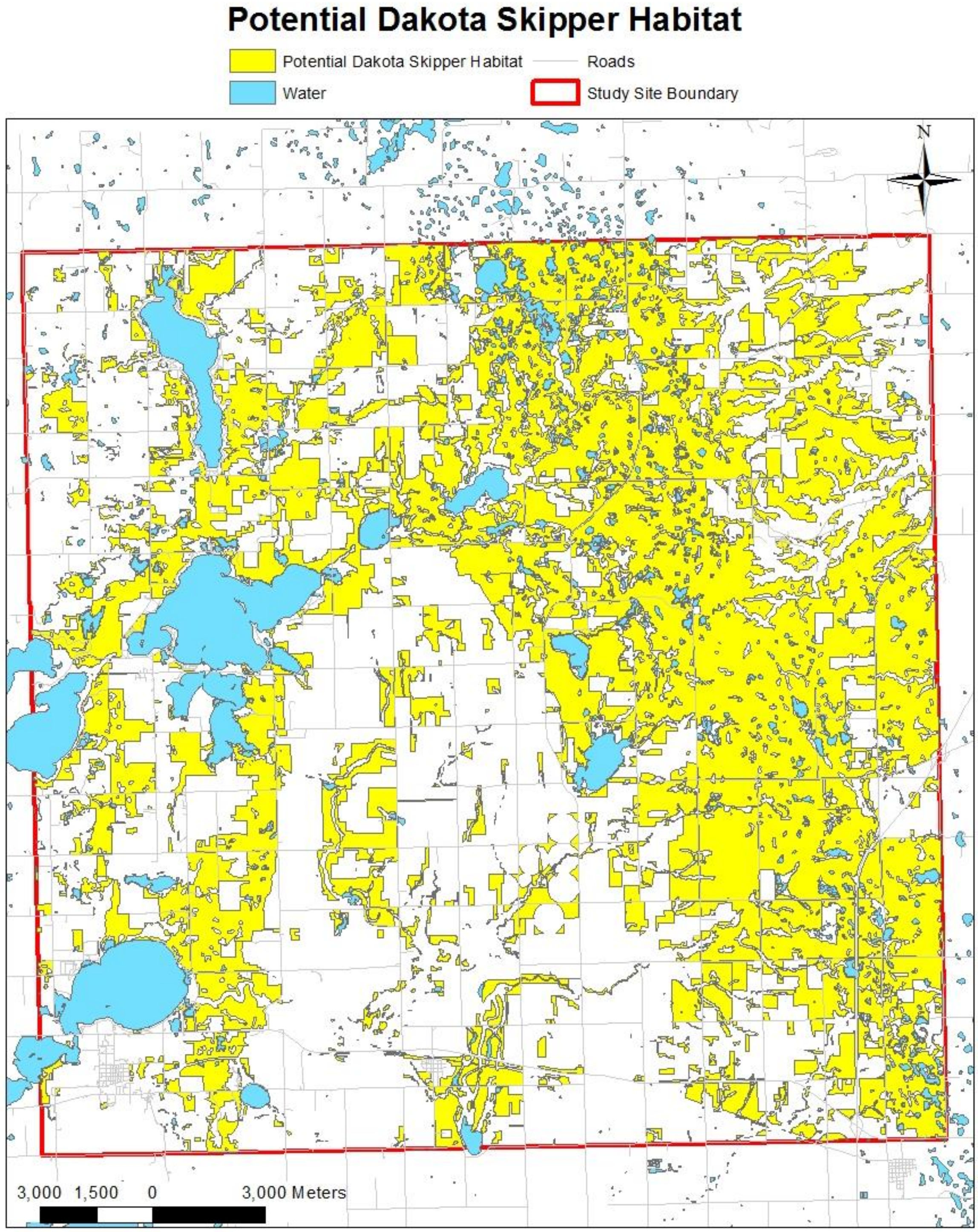

Figure 2.6. Map of study area with potential Dakota skipper habitat shown in yellow. The potential habitat layer identifies areas that have the potential to produce the plant communities that are used by the Dakota skipper.

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APPENDICES

Appendix A. Average Cover and Constancy of Species of Prairie Plant Communities

	Upland Dry Prairie		Dry-Mesic Prairie		Mesic Prairie	
Species	Average Cover (%)	Constancy (%)	Average Cover (%)	Constancy (%)	Average Cover (%)	Constancy (%)
Achillea millefolium	1.28	81.25	1.04	80.00	0.47	83.33
Agoseris glauca	0.03	37.50	0.56	35.56	1.28	83.33
Agrostis stricta	—	—	<0.01	4.44	—	—
Agrostis hyemalis	—	—	<0.01	2.22	—	—
Agrostis scabra	0.17	25.00	0.06	11.11	—	—
Agrostis stolonifera	—	—	0.11	6.67	0.83	33.33
Allium sp.	<0.01	6.25	<0.01	2.22	—	—
Allium stellatum	0.02	25.00	0.24	31.11	0.45	50.00
Allium textile	0.01	18.75	<0.01	6.67	—	—
Amaranthus retroflexus	—	—	—	—	—	—
Ambrosia psilostachya	0.95	50.00	0.85	53.33	0.42	16.67
Amorpha canescens	2.07	87.50	5.63	95.56	0.85	50.00
Andropogon gerardii	1.27	37.50	6.28	64.44	24.58	100.00
Anemone canadensis	0.01	6.25	0.39	20.00	—	—
Anemone cylindrica	0.21	62.50	0.94	88.89	0.03	33.33
Antennaria spp.*	0.63	37.50	1.18	60.00	1.67	66.67
Apocynum androsaemifolium	—	—	0.06	2.22	—	—
Apocynum cannabinum	0.01	12.50	0.01	17.78	<0.01	16.67
Arabis hirsuta	—	—	<0.01	13.33	0.01	33.33
Aristida purpurea	—	—	0.33	2.22	—	—

Appendix A. Continued.

Species	Upland Dry Prairie		Dry-Mesic Prairie		Mesic Prairie	
	Average Cover (%)	Constancy (%)	Average Cover (%)	Constancy (%)	Average Cover (%)	Constancy (%)
Artemisia absinthium	<0.01	6.25	0.12	11.11	—	—
Artemisia campestris	0.18	25.00	0.01	11.11	—	—
Artemisia frigida	1.30	75.00	0.02	22.22	—	—
Artemisia ludoviciana	0.47	18.75	1.23	55.56	—	—
Artemisia dracunculus	0.02	18.75	<0.01	2.22	—	—
Asclepias spp.**	<0.01	6.25	0.08	33.33	—	—
Asclepias pumila	—	—	<0.01	6.67	—	—
Asclepias viridula	0.02	25.00	<0.01	6.67	—	—
Astragalus spp.***	—	—	<0.01	2.22	—	—
Astragalus agrestis	0.01	6.25	0.06	8.89	0.42	16.67
Astragalus adsurgens	0.36	68.75	0.01	8.89	—	—
Astragalus canadensis	0.18	31.25	0.01	17.78	—	—
Astragalus crassicarpus	0.37	81.25	1.03	62.22	—	—
Astragalus flexuosus	1.12	43.75	0.02	17.78	—	—
Avenula hookeri	0.03	25.00	<0.01	4.44	—	—
Bouteloua curtipendula	0.18	25.00	4.06	53.33	0.42	16.67
Bouteloua gracilis	0.81	56.25	0.06	11.11	—	—
Brickellia eupatorioides	—	—	<0.01	2.22	—	—
Bromus inermis	3.13	75.00	5.62	88.89	3.33	50.00
Calamagrostis canadensis	—	—	0.06	2.22	—	—

Appendix A. Continued.

	Upland Dry Prairie		Dry-Mesic Prairie		Mesic Prairie	
Species	Average Cover (%)	Constancy (%)	Average Cover (%)	Constancy (%)	Average Cover (%)	Constancy (%)
Calamagrostis stricta	—	—	—	—	0.02	16.67
Calamovilfa longifolia	0.47	18.75	<0.01	6.67	—	—
Calylophus serrulatus	0.18	37.50	0.30	37.78	—	—
Carex filifolia	0.17	18.75	—	—	—	—
Carex inops	0.16	6.25	—	—	—	—
Carex spp.****	0.32	25.00	0.85	24.44	0.87	66.67
Castilleja sessiliflora	0.33	37.50	0.06	6.67	—	—
Cerastium arvense	0.48	31.25	<0.01	4.44	—	—
Chenopodium spp.*****	0.18	31.25	0.18	15.56	—	—
Cirsium arvense	0.01	12.50	0.06	6.67	—	—
Cirsium flodmanii	0.53	81.25	1.32	97.78	2.10	100.00
Comandra umbellata	1.74	87.50	1.24	68.89	0.47	66.67
Convolvulus arvense	0.02	37.50	0.01	15.56	—	—
Conyza Canadensis	0.01	12.50	<0.01	4.44	—	—
Crepis runcinata	—	—	—	—	0.07	16.67
Dalea candida	—	—	0.34	15.56	0.84	50.00
Dalea purpurea	1.93	100.00	1.92	84.44	0.02	16.67
Delphinium carolinianum	0.02	43.75	0.03	40.00	—	—
Dichanthelium spp.******	0.01	6.25	0.11	4.44	0.09	66.67

Appendix A. Continued.

Species	Upland Dry Prairie Average Cover (%)	Upland Dry Prairie Constancy (%)	Dry-Mesic Prairie Average Cover (%)	Dry-Mesic Prairie Constancy (%)	Mesic Prairie Average Cover (%)	Mesic Prairie Constancy (%)
Dichanthelium depauperatum	—	—	<0.01	4.44	—	—
Dichanthelium linearifolium	—	—	<0.01	2.22	—	—
Dichanthelium sp.	0.01	6.25	2.46	71.11	0.85	66.67
Dichanthelium wilcoxianum	0.01	6.25	0.12	15.56	—	—
Echinacea angustifolia	3.01	100.00	1.26	82.22	0.02	33.33
Elymus canadensis	—	—	—	—	0.42	16.67
Elymus repens	0.01	12.50	0.17	15.56	—	—
Elymus trachycaulus	0.19	43.75	0.25	40.00	0.03	33.33
Equisetum arvense	—	—	—	—	0.03	33.33
Equisteum laevigatum	—	—	0.06	8.89	0.03	33.33
Erigeron sp.	—	—	<0.01	2.22	—	—
Erigeron strigosus	0.03	43.75	0.18	33.33	0.47	66.67
Erysimum sp.	—	—	<0.01	2.22	—	—
Euphorbia esula	—	—	<0.01	2.22	—	—
Euthamia graminifolia	—	—	0.06	2.22	—	—
Fragaria virginiana	—	—	0.12	8.89	0.03	33.33
Gaillardia aristata	0.05	68.75	0.01	8.89	—	—
Galium boreale	3.44	81.25	3.39	93.33	1.70	100.00
Gaura coccinea	0.50	50.00	0.06	6.67	—	—
Gentiana andrewsii	—	—	—	—	0.02	16.67

Appendix A. Continued.

	Upland Dry Prairie		Dry-Mesic Prairie		Mesic Prairie	
Species	Average Cover (%)	Constancy (%)	Average Cover (%)	Constancy (%)	Average Cover (%)	Constancy (%)
Gentiana puberlenta	0.01	6.25	<0.01	4.44	0.02	16.67
Gentiana spp.******	—	—	—	—	0.02	16.67
Geum triflorum	0.01	18.75	0.07	26.67	0.03	33.33
Glycine max	0.01	6.25	—	—	—	—
Glycyrrhiza lepidota	—	—	0.72	8.89	—	—
Grindelia squarrosa	0.01	12.50	0.01	6.67	—	—
Hedeoma hispida	—	—	0.06	4.44	—	—
Helenium autumnale	—	—	—	—	<0.01	16.67
Helianthus maximiliani	<0.01	6.25	0.34	22.22	1.27	66.67
Helianthus pauciflorus	3.59	50.00	3.24	86.67	0.42	33.33
Heliopsis helianthoides	0.01	12.50	0.01	15.56	0.42	33.33
Hesperostipa comata	4.39	62.50	1.89	13.33	—	—
Hesperostipa spartea	12.04	93.75	22.01	95.56	3.34	66.67
Heterotheca villosa	0.53	81.25	<0.01	4.44	—	—
Heuchera richardsonii	0.07	87.50	0.01	22.22	—	—
Hieracium canadense	—	—	<0.01	2.22	0.02	33.33
Hieracium umbellatum	<0.01	6.25	<0.01	2.22	0.02	16.67
Juniperus virginiana	—	—	<0.01	2.22	—	—
Koeleria macrantha	0.51	62.50	0.07	15.56	0.03	33.33
Lactuca spp.*******	—	—	<0.01	4.44	0.02	16.67

Appendix A. Continued.

Species	Upland Dry Prairie		Dry-Mesic Prairie		Mesic Prairie	
	Average Cover (%)	Constancy (%)	Average Cover (%)	Constancy (%)	Average Cover (%)	Constancy (%)
Lactuca serriola	—	—	0.06	15.56	0.42	16.67
Lactuca tatarica	0.79	43.75	0.02	15.56	—	—
Lathyrus venosus	0.01	12.50	0.17	13.33	—	—
Liatris spp.********	0.02	25.00	0.48	55.56	2.10	100.00
Liatris punctata	2.04	87.50	0.29	33.33	—	—
Lilium philadelphicum	0.16	6.25	0.01	11.11	0.02	33.33
Linaria vulgaris	—	—	<0.01	2.22	—	—
Linum lewisii	0.01	6.25	—	—	—	—
Linum rigidum	0.98	75.00	0.09	37.78	0.02	33.33
Lithospermum canescens	0.05	50.00	0.26	64.44	—	—
Lithospermum incisum	0.03	25.00	<0.01	4.44	—	—
Lobelia spicata	0.03	25.00	0.01	13.33	0.10	100.00
Lomatium foeniculaceum	0.16	6.25	—	—	—	—
Lygodesmia juncea	0.01	6.25	<0.01	6.67	—	—
Escobaria vivipara	0.01	6.25	<0.01	2.22	—	—
Medicago lupulina	1.41	31.25	0.28	17.78	1.27	66.67
Medicago sativa	0.03	25.00	0.33	6.67	0.02	16.67
Melilotus officinalis	0.95	50.00	0.97	57.78	0.88	83.33
Mirabilis hirsuta	0.01	12.50	0.01	8.89	—	—
Monarda fistulosa	0.01	6.25	1.35	48.89	0.02	33.33
Muhlenbergia sp.	—	—	0.06	4.44	—	—

Appendix A. Continued.

Species	Upland Dry Prairie		Dry-Mesic Prairie		Mesic Prairie	
	Average Cover (%)	Constancy (%)	Average Cover (%)	Constancy (%)	Average Cover (%)	Constancy (%)
Muhlenbergia cuspidata	0.16	6.25	—	—	0.42	16.67
Nassella viridula	3.31	62.50	0.79	35.56	—	—
Oenothera vilosa	—	—	0.00	4.44	—	—
Oligoneuron rigidum	0.33	37.50	1.87	77.78	0.05	50.00
Oligoneuron ptarmicoides	—	—	<0.01	4.44	0.02	16.67
Onosmodium bejariense	0.03	25.00	0.08	35.56	0.02	16.67
Orthocarpus luteus	0.16	18.75	<0.01	4.44	—	—
Oxalis stricta	0.48	25.00	0.29	26.67	<0.01	16.67
Oxalis dillenii	—	—	<0.01	2.22	—	—
Oxalis violacea	0.01	12.50	0.17	11.11	—	—
Oxytropis lambertii	0.02	37.50	<0.01	4.44	—	—
Packera sp.	—	—	—	—	0.02	16.67
Panicum capillare	—	—	—	—	<0.01	16.67
Panicum virgatum	1.09	12.50	0.67	22.22	2.92	33.33
Pascopyrum smithii	—	—	<0.01	2.22	—	—
Pediomelum canadensis	0.16	6.25	0.44	6.67	1.68	83.33
Pediomelum argophyllum	1.41	62.50	1.91	71.11	0.42	16.67
Pediomelum esculentum	0.24	93.75	0.12	82.22	—	—
Penstemon sp.	—	—	<0.01	2.22	—	—
Penstemon gracilis	0.03	62.50	0.03	40.00	—	—
Penstemon albidus	0.01	6.25	—	—	—	—

Appendix A. Continued.

Species	Upland Dry Prairie		Dry-Mesic Prairie		Mesic Prairie	
	Average Cover (%)	Constancy (%)	Average Cover (%)	Constancy (%)	Average Cover (%)	Constancy (%)
Penstemon gracilis	0.01	12.50	<0.01	0.03	—	—
Phleum pratense	0.01	6.25	0.62	35.56	8.75	100.00
Physalis virginiana	0.36	75.00	0.56	86.67	—	—
Poa compressa	—	—	—	—	—	—
Poa pratensis	6.25	93.75	4.79	88.89	4.17	83.33
Polygala alba	0.01	12.50	—	—	—	—
Polygala verticillata	0.48	31.25	<0.01	4.44	—	—
Potentilla anserina	—	—	—	—	0.02	16.67
Potentilla arguta	0.03	37.50	0.04	48.89	—	—
Potentilla pensylvanica	0.20	56.25	0.01	8.89	—	—
Prenanthes racemosa	—	—	<0.01	2.22	0.04	66.67
Prunus americana	0.00	6.25	0.01	8.89	—	—
Prunus virginiana	—	—	<0.01	2.22	—	—
Pulsatilla patens	1.13	81.25	0.31	46.67	—	—
Ratibida columnifera	0.35	50.00	0.53	46.67	—	—
Rhus glabra	—	—	<0.01	2.22	—	—
Rosa arkansana	0.18	25.00	0.98	80.00	0.05	50.00
Rudbeckia hirta	<0.01	6.25	<0.01	2.22	0.05	50.00
Salsola spp.*********	—	—	0.06	4.44	—	—

Appendix A. Continued.

	Upland Dry Prairie		Dry-Mesic Prairie		Mesic Prairie	
Species	Average Cover (%)	Constancy (%)	Average Cover (%)	Constancy (%)	Average Cover (%)	Constancy (%)
Schizachyrium scoparium	15.01	93.75	9.95	86.67	1.68	83.33
Setaria glauca	—	—	<0.01	2.22	—	—
Setaria pumila	—	—	<0.01	2.22	—	—
Silene antirrhina	0.16	6.25	—	—	—	—
Silene drummondii	<0.01	6.25	—	—	—	—
Sisyrinchium campestre	0.16	6.25	<0.01	2.22	—	—
Solidago canadensis	0.81	18.75	2.46	62.22	0.85	50.00
Solidago missouriensis	—	81.25	0.58	48.89	0.43	33.33
Solidago nemoralis	0.01	—	<0.01	2.22	—	—
Sorghastrum nutans	—	6.25	0.56	17.78	5.42	50.00
Spartina pectinata	4.88	—	1.50	6.67	2.50	16.67
Sporobolus heterolepis	0.01	68.75	2.52	55.56	0.47	66.67
Stachys palustris	0.48	6.25	—	—	—	—
Symphoricarpos occidentalis	1.43	37.50	1.29	66.67	—	—
Symphyotrichum ericoides	—	87.50	1.30	75.56	1.28	83.33
Symphyotrichum lanceolatum	0.01	—	—	—	<0.01	16.67
Symphyotrichum oblongifolium	0.81	18.75	0.17	13.33	—	—
Symphyotrichum sericeum	0.38	62.50	1.53	88.89	0.02	16.67
Taraxacum officinale	0.38	87.50	0.31	53.33	0.50	100.00

Appendix A. Continued.

	Upland Dry Prairie		Dry-Mesic Prairie		Mesic Prairie	
Species	Average Cover (%)	Constancy (%)	Average Cover (%)	Constancy (%)	Average Cover (%)	Constancy (%)
Thalictrum venulosum	0.33	25.00	0.20	44.44	8.33	83.33
Toxicodendron rydbergii	—	—	<0.01	2.22	—	—
Tragopogon dubius	0.38	87.50	0.10	64.44	0.02	33.33
Trifolium pratense	—	—	0.01	11.11	0.47	66.67
Trifolium repens	—	—	0.06	2.22	0.02	16.67
Ulmus americana	<0.01	6.25	—	—	—	—
Verbena stricta	0.16	18.75	0.06	6.67	—	—
Vicia americana	0.01	6.25	—	—	—	—
Viola sp.	—	—	—	—	0.02	16.67
Viola nuttallii	<0.01	6.25	—	—	—	—
Viola pedatifida	0.38	81.25	1.10	91.11	0.02	16.67
Viola pratincola	—	—	—	—	0.42	16.67
Zigadenus elegans	0.03	31.25	0.68	40.00	1.70	100.00
Zizia aptera	0.16	12.50	0.32	57.78	2.50	100.00
Zizia aurea	—	—	0.01	17.78	0.88	83.33

*Includes species *Antennaria parvifolia* and/or *Antennaria neglecta*
**Includes species *Asclepias speciosa* and/or *Asclepias syriaca*
***Includes more than three species that could be identified to the genus *Astragalus*
****Includes more than three species that could be identified to the genus *Carex*
*****Includes species *Dichanthelium oligosanthes* and/or *Dichanthelium leibergii*
******Includes species *Gentiana andrewsii* and/or *Gentiana puberulenta*
*******Includes more than three species that could be identified to the genus Lactuca
********Includes species *Liatris aspera* and/or *Liatris ligulistylis*
*********Includes more than three species that could be identified to the genus *Salsola*

Appendix B. Maps of Site and Transect Locations

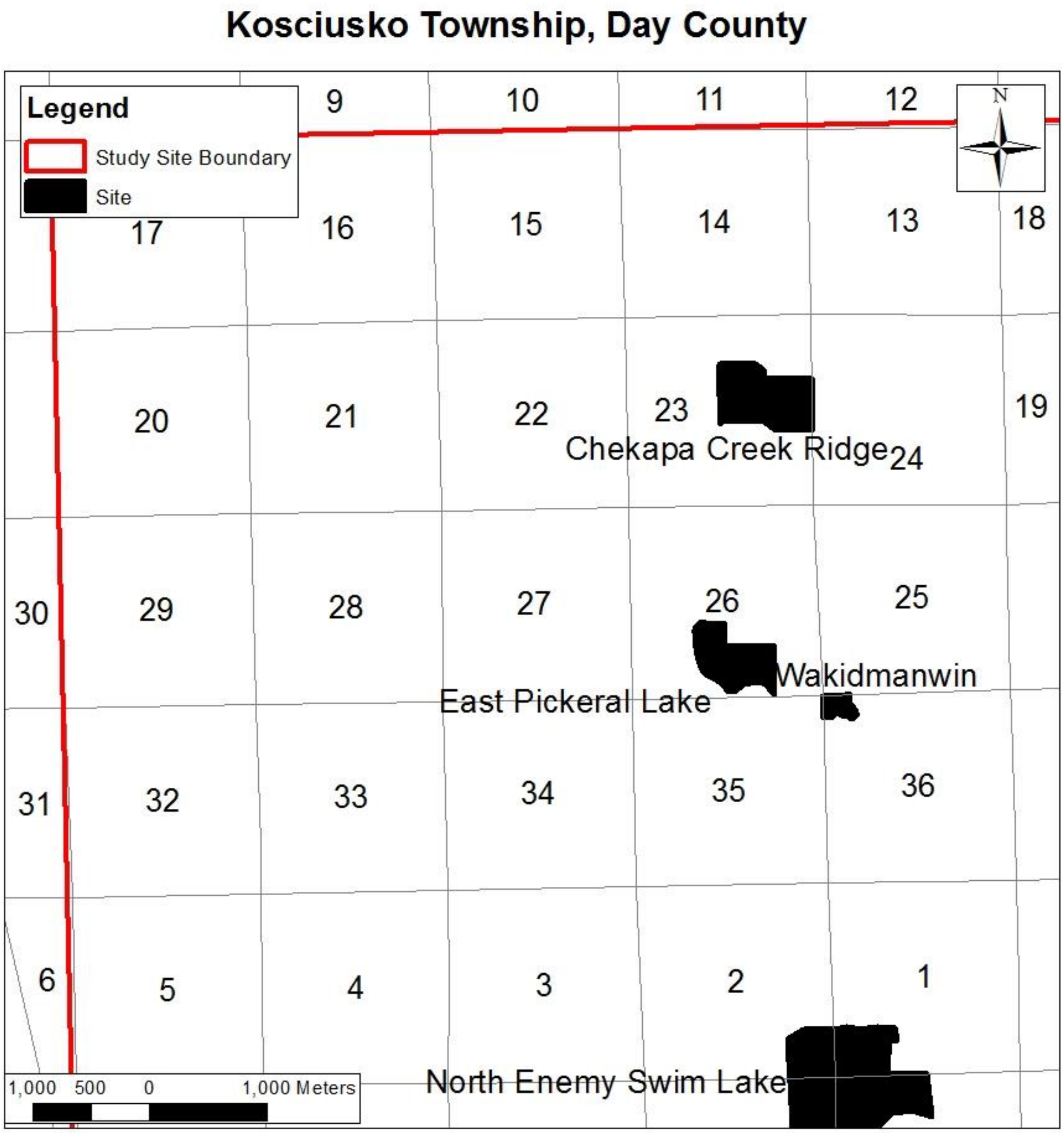

Figure B1. Locations of sites where transects were sampled in Kosciusko Township, Day County, including Chekapa Creek Ridge, East Pickeral Lake, Wakidmanwin, and North Enemy Swim Lake.

Appendix B. Continued.

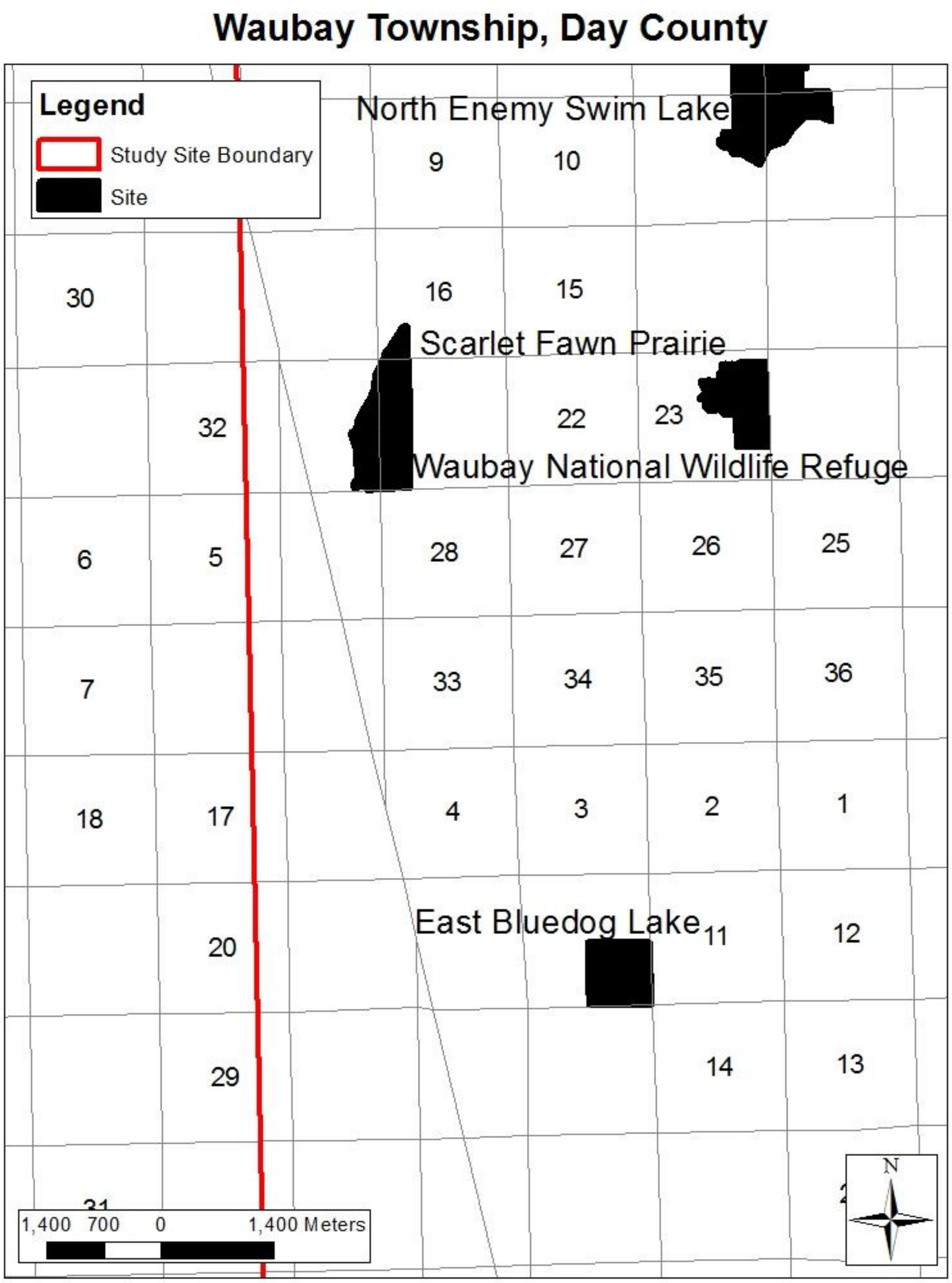

Figure B2. Locations of sites in Waubay Township, Day County, including North Enemy Swim Lake, Scarlet Fawn Prairie, Waubay National Wildlife Refuge, and East Bluedog Lake.

Appendix B. Continued.

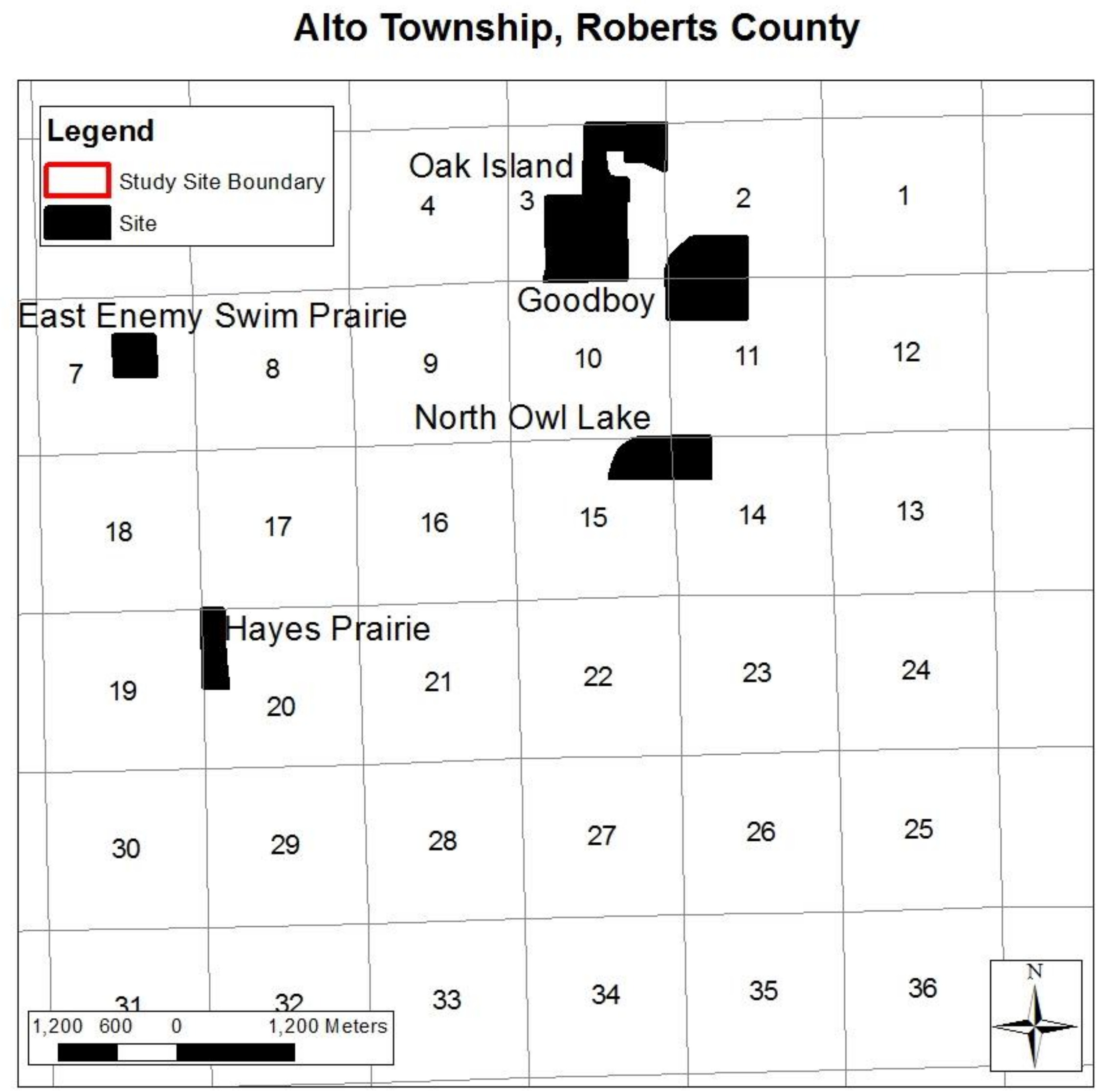

Figure B3. Locations of sites in Alto Township, Day County, including Oak Island, East Enemy Swim Prairie, Goodboy, North Owl Lake, and Hayes Prairie.

Appendix B. Continued.

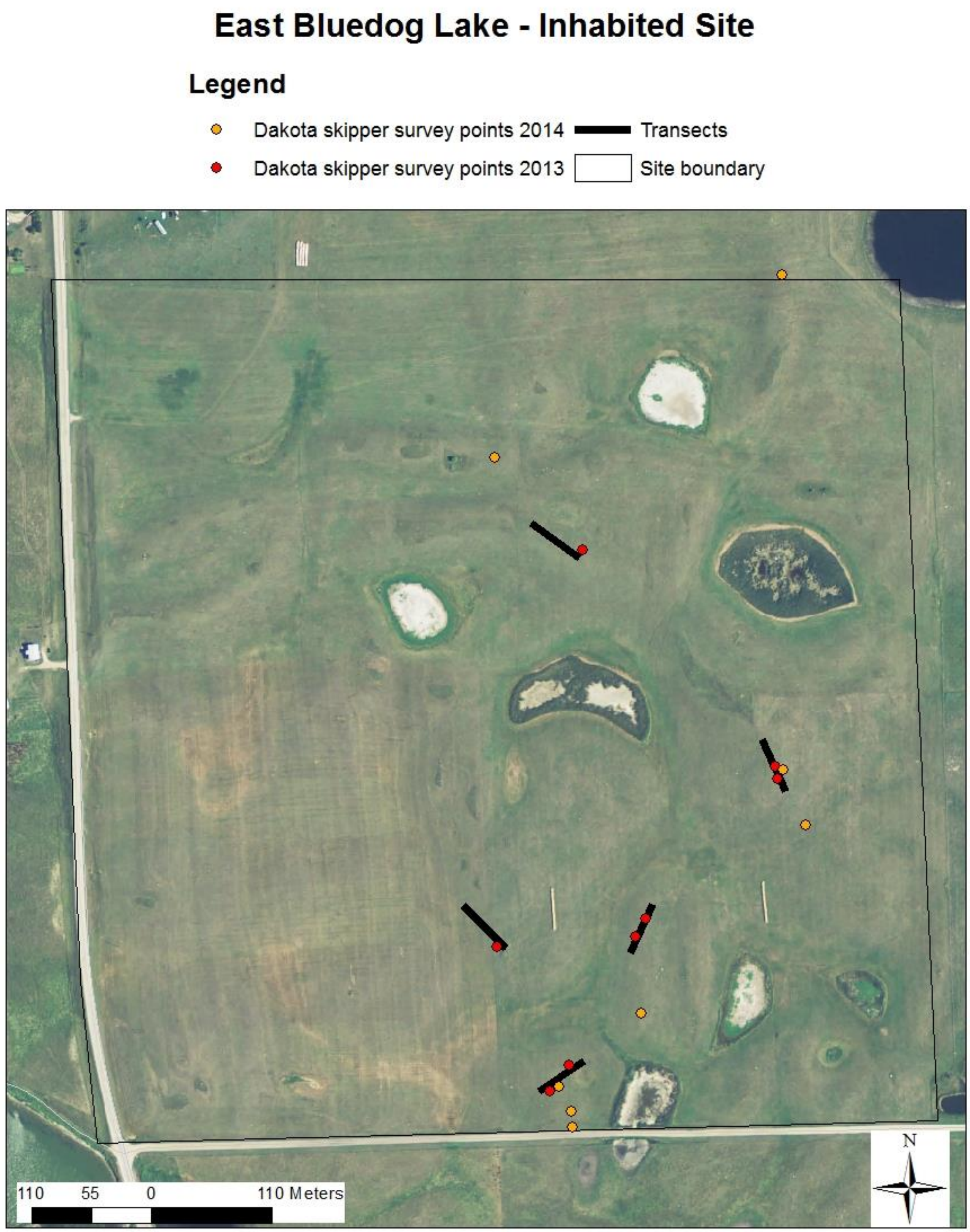

Figure B3. Map of transects sampled at East Bluedog Lake. Postiive Dakota skipper survey points from 2013 in orange and 2014 in yellow.

Appendix B. Continued.

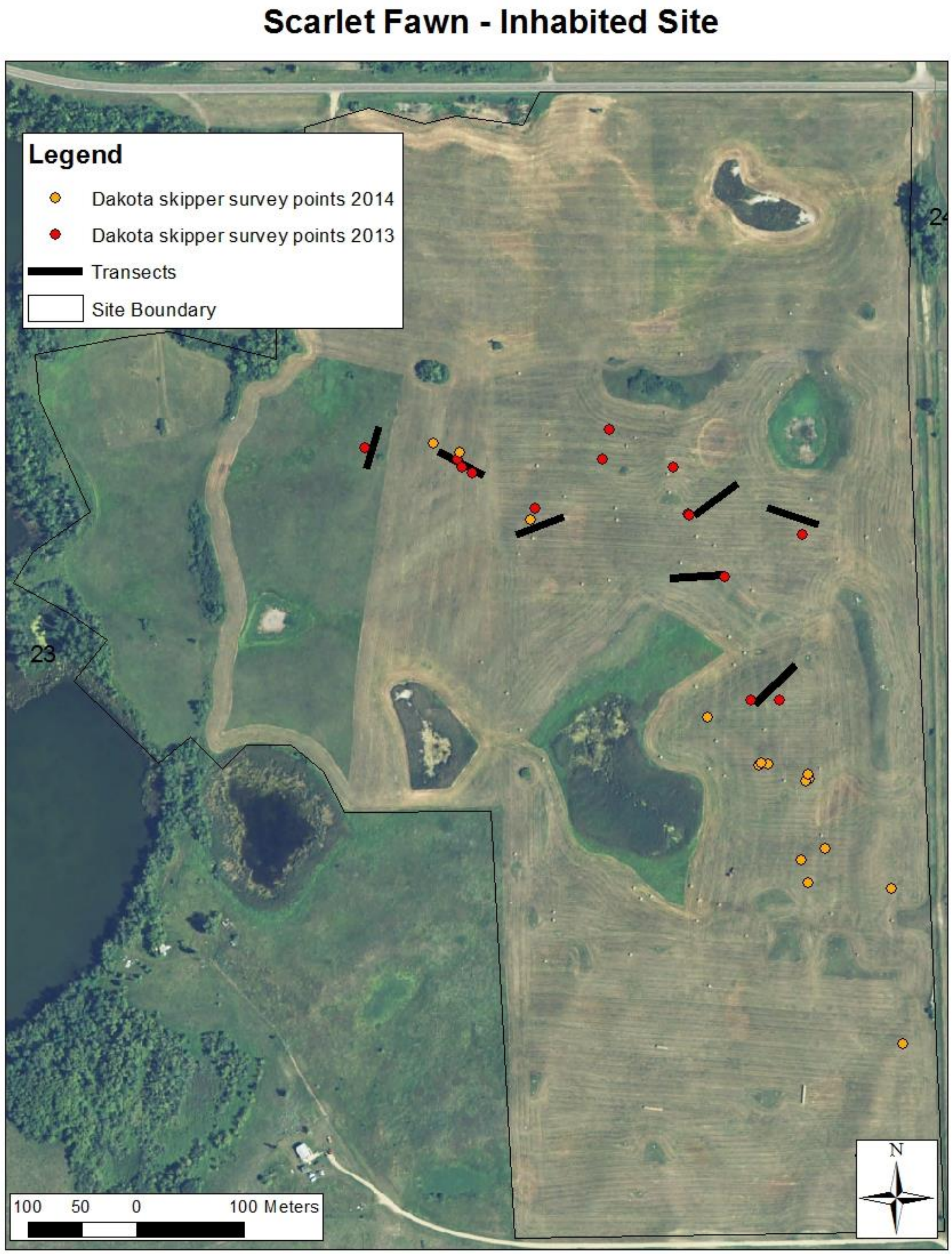

Figure B4. Map of transects sampled at Scarlet Fawn Prairie. Positive Dakota skipper survey points from 2013 in orange and 2014 in yellow.

Appendix B. Continued.

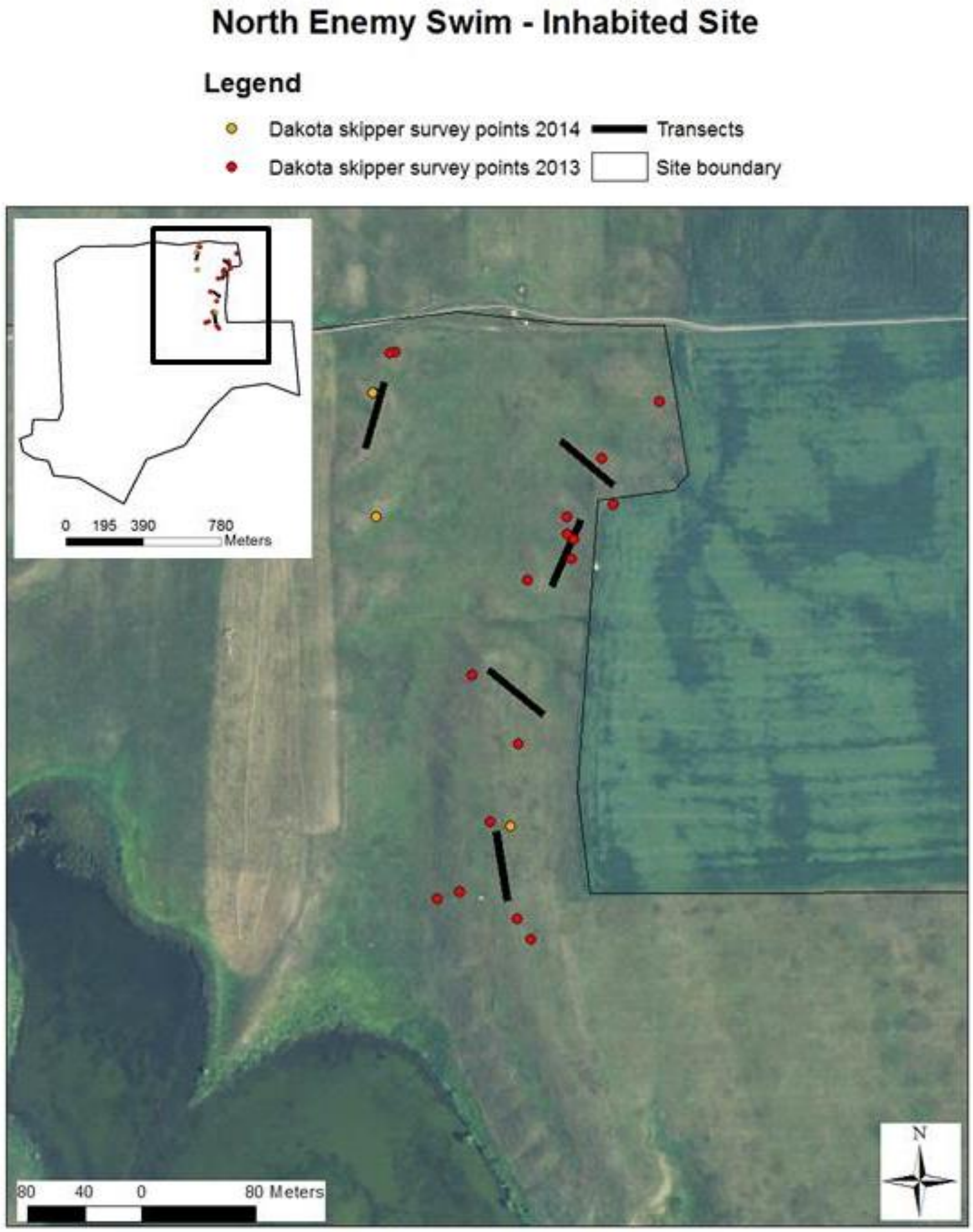

Figure B5. Map of transects sampled at North Enemy Swim. Positive Dakota skipper survey points from 2013 in orange and 2014 in yellow.

Appendix B. Continued.

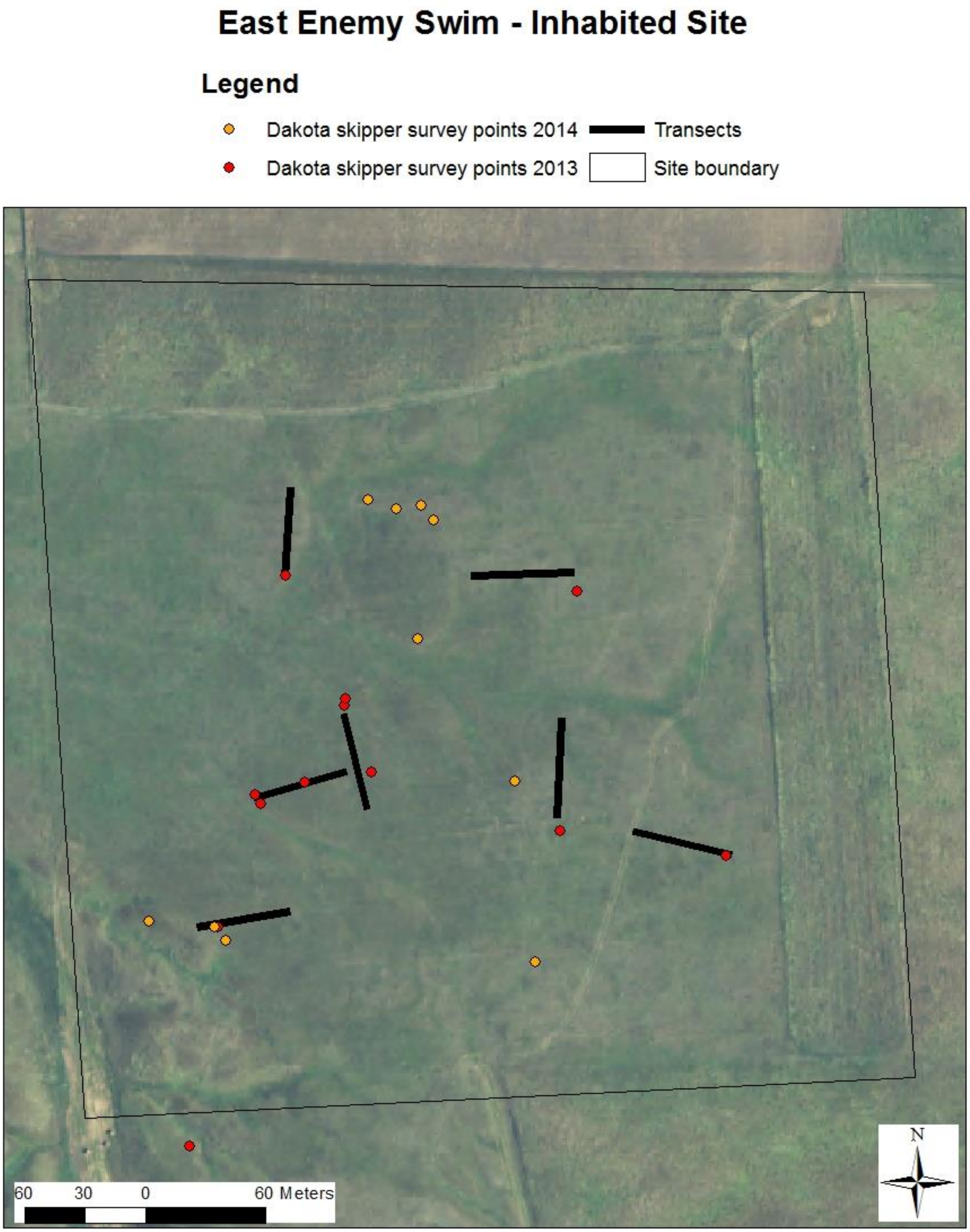

Figure B6. Map of transects sampled at East Enemy Swim. Positive Dakota skipper survey points from 2013 in orange and 2014 in yellow.

Appendix B. Continued.

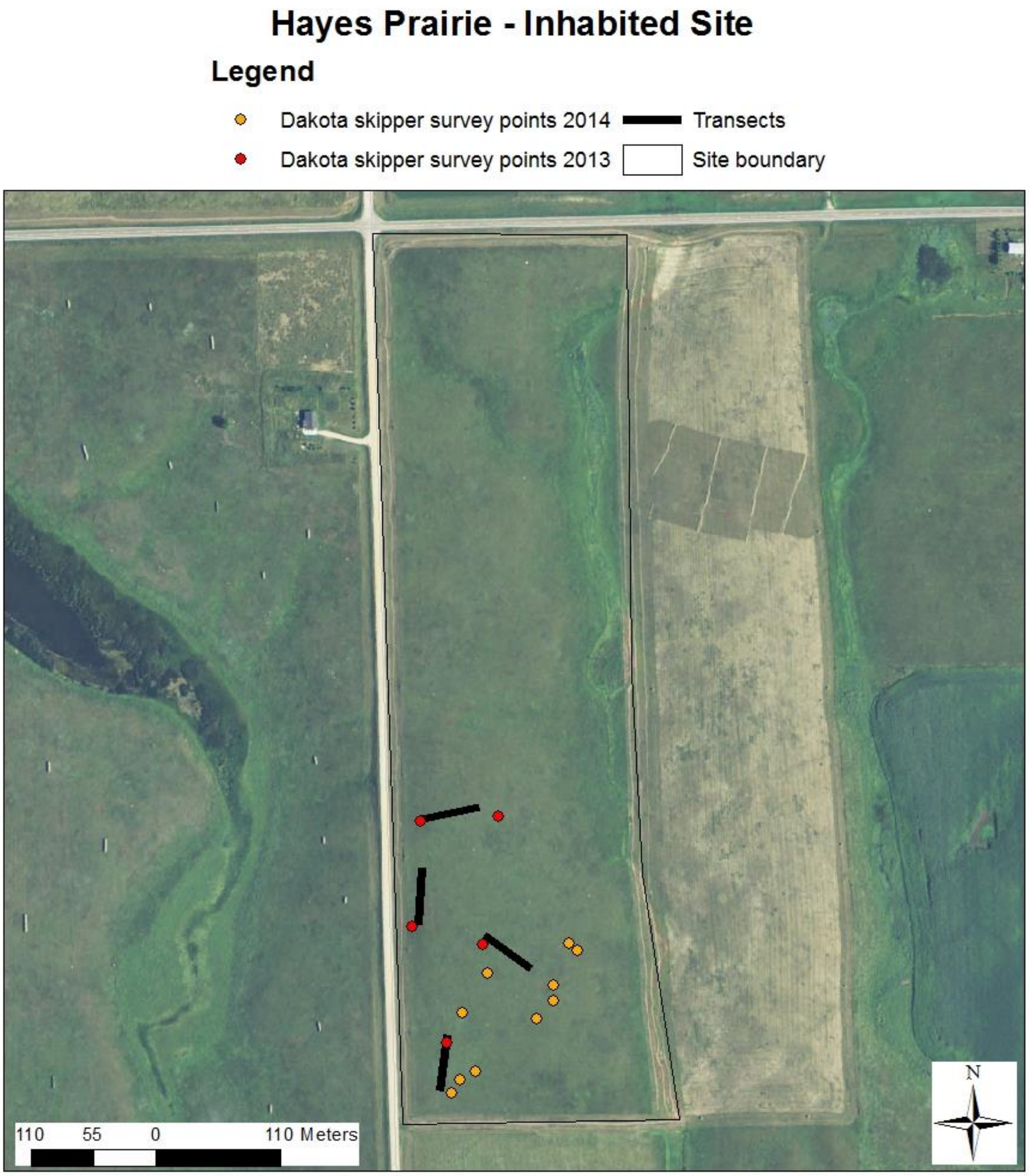

Figure B7. Map of transects sampled at Hayes Prairie. Positive Dakota skipper survey points from 2013 in orange and 2014 in yellow.

Appendix B. Continued.

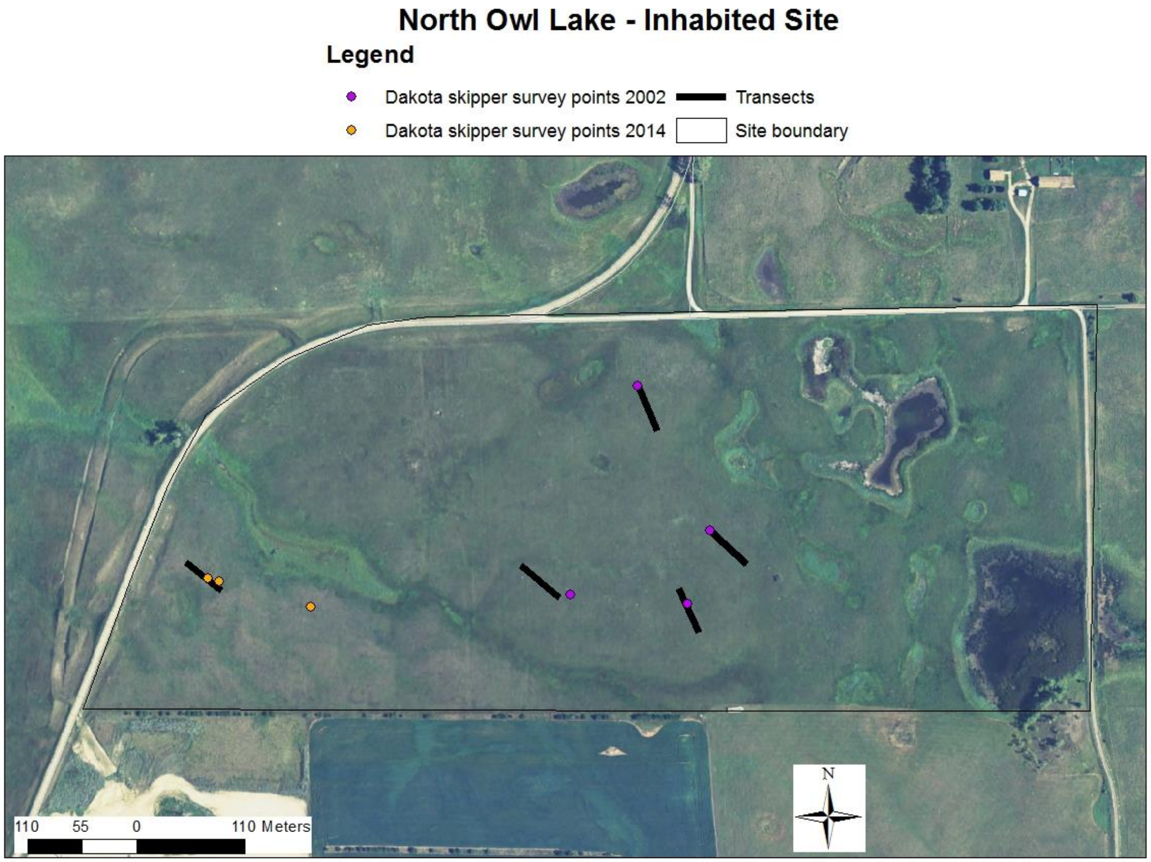

Figure B8. Map of transects sampled at North Owl Lake. Positive Dakota skipper survey points from 2002 in purple and 2014 in yellow.

Appendix B. Maps of Transect and Site Locations

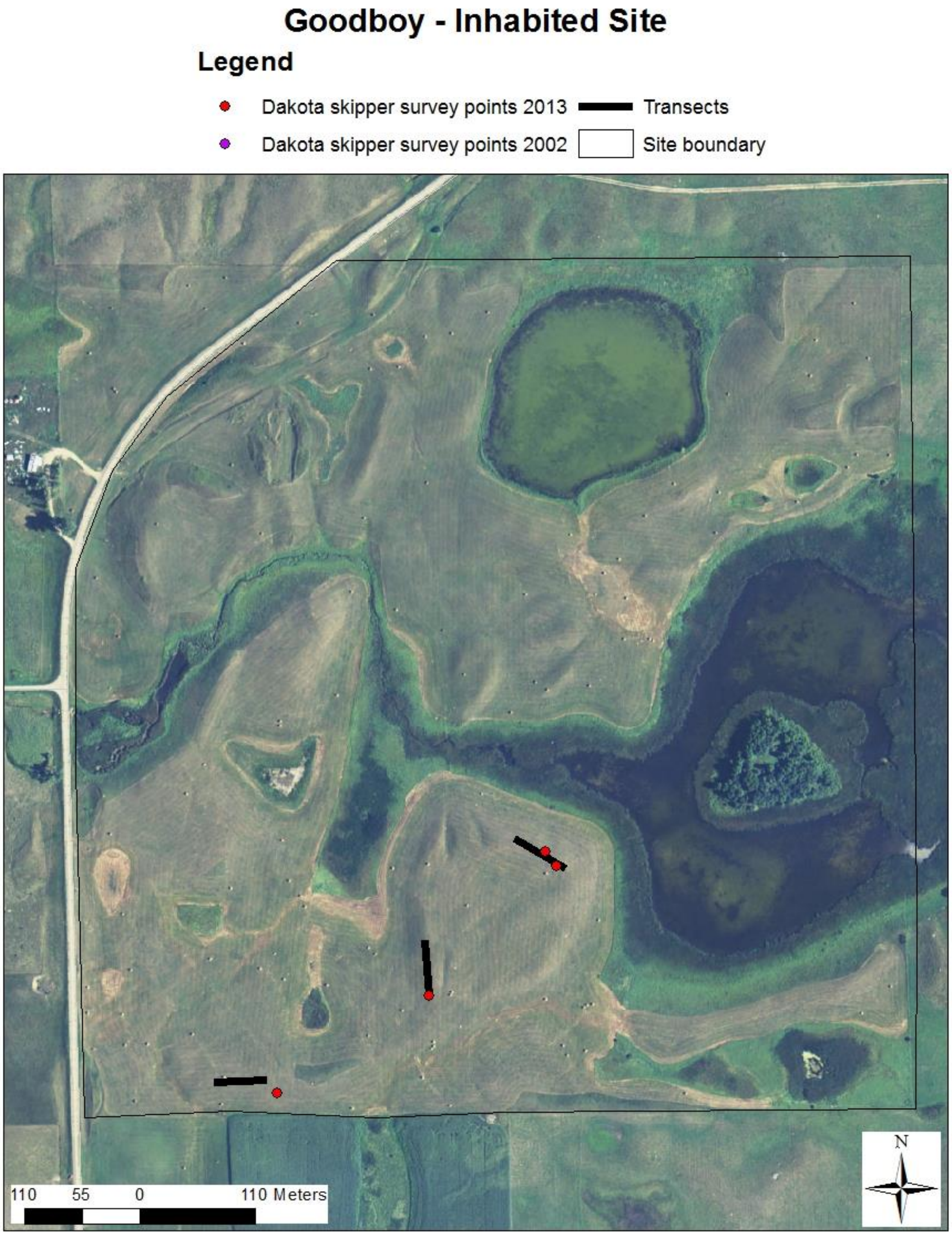

Figure B9. Map of transects sampled at Goodboy prairie. Positive Dakota skipper survey points from 2014 in orange.

Appendix B. Maps of Transect and Site Locations

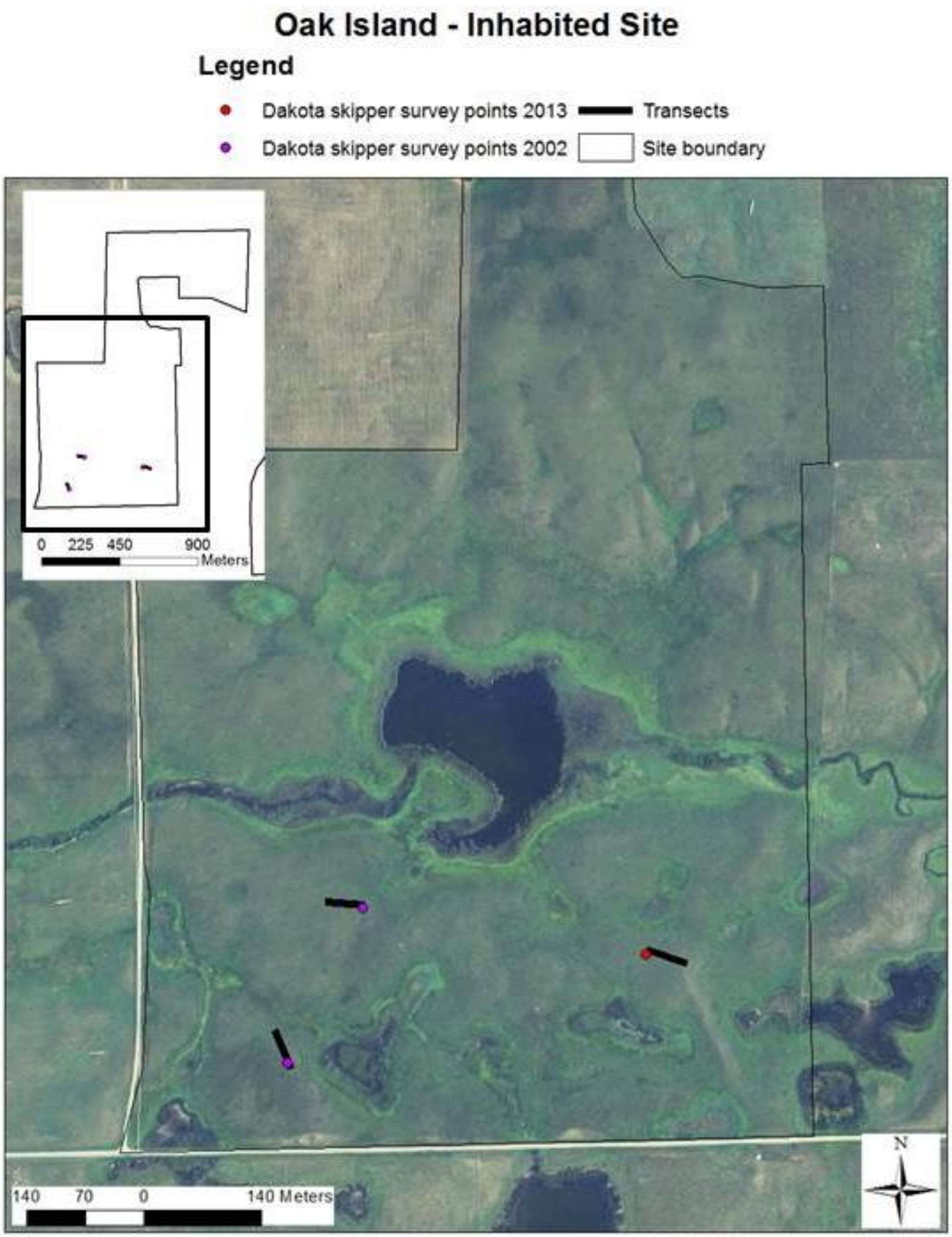

Figure B10. Map of transects sampled at Oak Island. Positive Dakota skipper survey points from 2002 in purple and 2014 in orange.

Appendix B. Maps of Transect and Site Locations

Figure B11. Map of transects sampled at Wakidmanwin prairie. Positive Dakota skipper survey points from 2002 in purple.

Appendix B. Maps of Transect and Site Locations

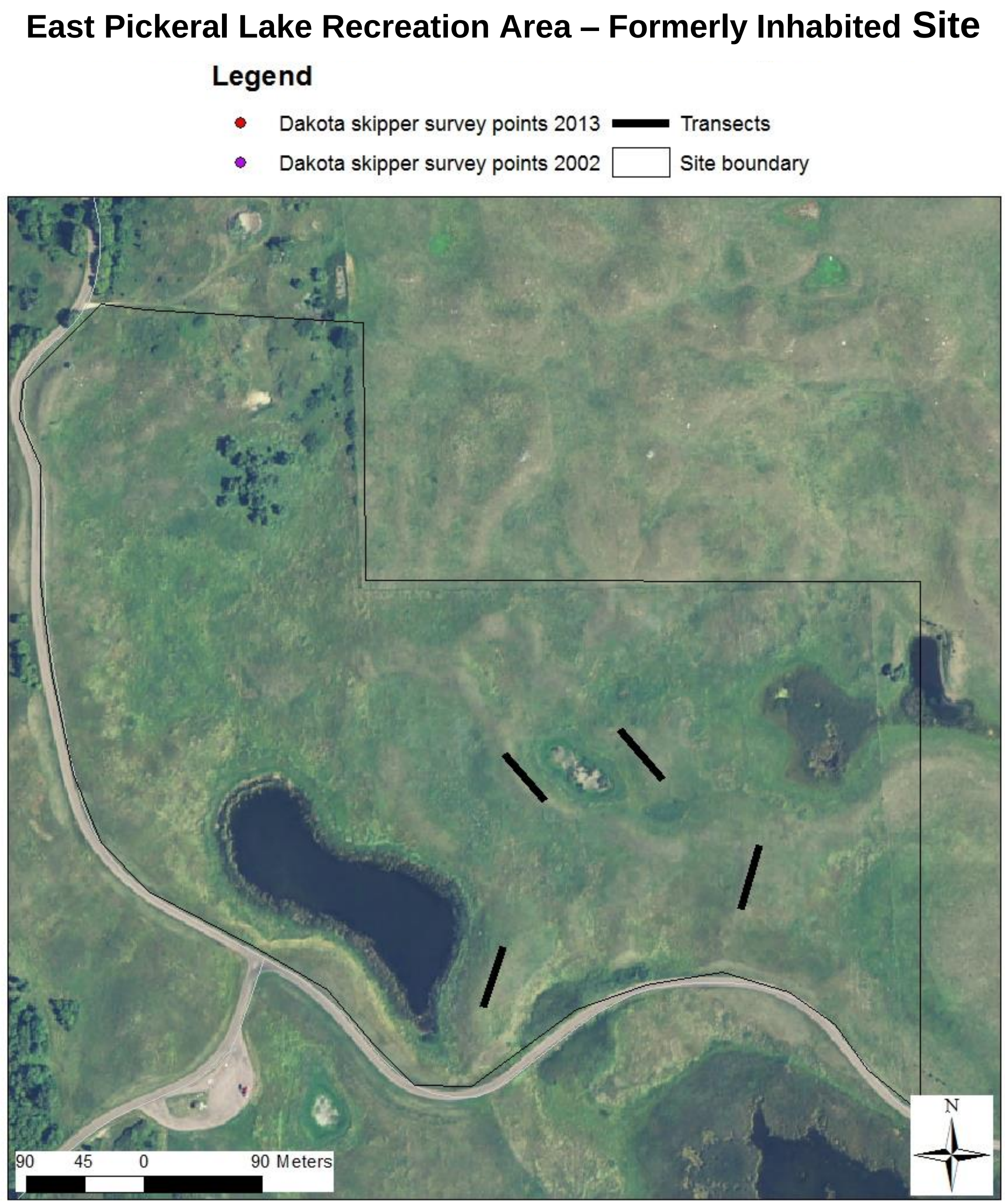

Figure B12. Map of transects sampled at East Pickerel Lake Recreation Area. There were no gps locations from previous surveys at this site. The surveyor, Dennis Skadsen, pointed out the ridges where Dakota skippers had been found in previous years when populations were still present.

Appendix B. Maps of Transect and Site Locations

Figure B13. Map of transects sampled at Chekapa Creek Ridge. There were no gps locations from previous surveys at this site. The surveyor, Dennis Skadsen, pointed out the ridge where Dakota skippers had been found in previous years when populations were still present.

Appendix B. Maps of Transect and Site Locations

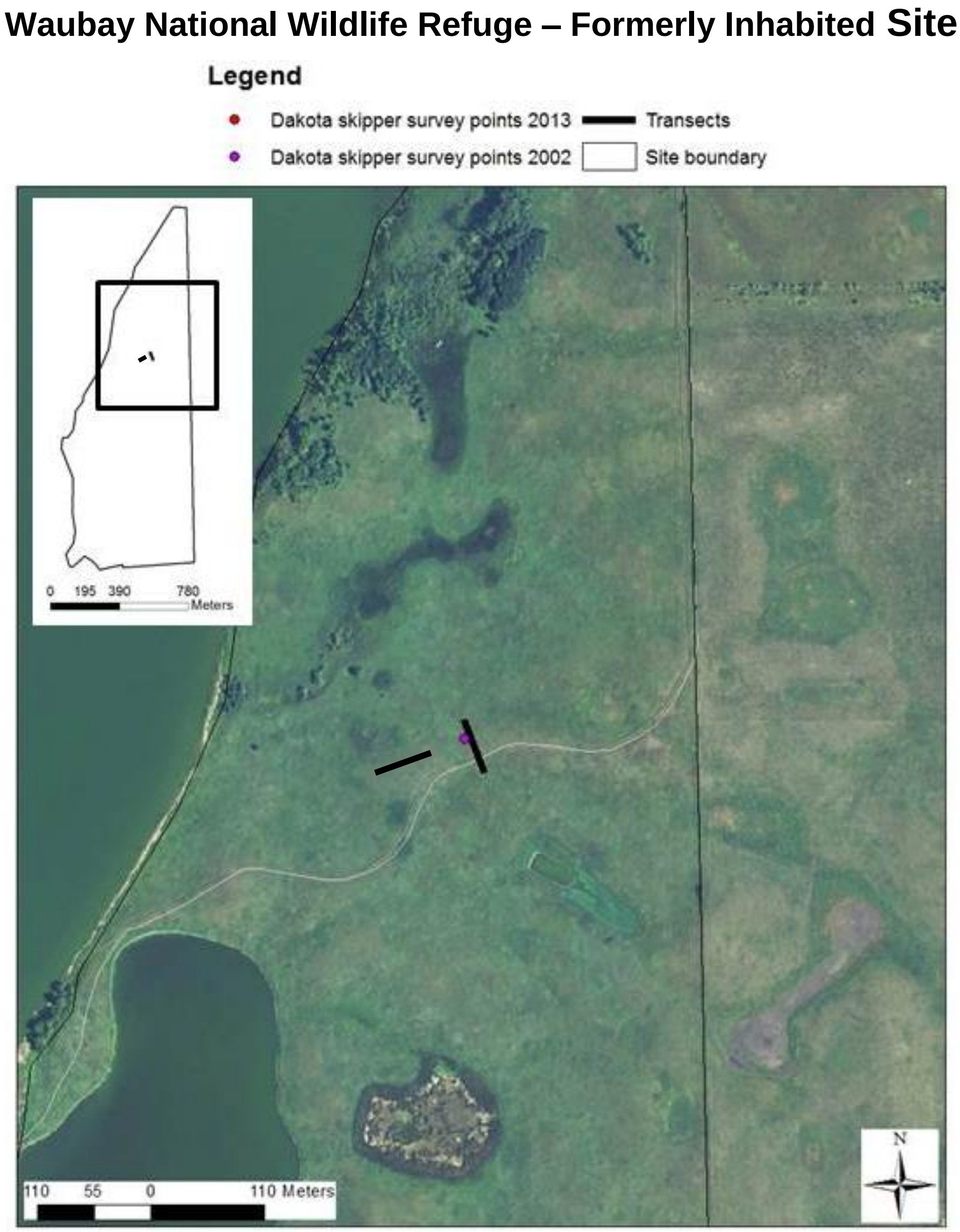

Figure B14. Map of transect sampled at Waubay National Wildlife Refuge. Positive Dakota skipper survey points from 2002 in purple.

Appendix C. Average Abundance and Frequency Values of Species of Inhabited and Formerly Inhabited Transects

	Inhabited Transects		Formerly Inhabited Transects	
Species	Average Cover (%), SE	Frequency (%)	Average Cover (%), SE	Frequency (%)
Achillea millefolium	0.17 ± 0.02	74.36	0.23 ± 0.15	50
Agoseris glauca	0.27 ± 0.09	43.59	0.08 ± 0.06	20
Allium sp.	<0.01	2.56	—	—
Allium stellatum	0.03 ± 0.01	25.64	—	—
Allium textile	0.04 ± .01	35.90	—	—
Ambrosia psilostachya	0.06 ± 0.03	20.51	0.09 ± 0.03	60
Amorpha canescens	2.03 ± 0.38	74.36	2.13 ± 0.87	60
Andropogon gerardii	0.59 ± 0.16	48.72	4.78 ± 2.80	50
Androsace occidentalis	0.01 ± <0.01	5.13	—	—
Anemone canadensis	0.03 ± 0.20	10.26	0.12 ± 0.11	20
Anemone cylindrica	0.51 ± 0.09	79.49	0.23 ± 0.0764	90
Antennaria parvifolia	0.16 ± 0.03	61.54	0.06 ± 0.05	20
Apocynum cannabinum	—	—	0.01 ± 0.01	10
Arabis hirsuta	0.04 ± 0.01	35.90	0.01 ± 0.01	10
Artemisia campestris	<0.01	5.13	0.01 ± 0.01	10
Artemisia frigida	0.03 ± 0.01	20.51	0.07 ± 0.05	20
Artemisia ludoviciana	0.06 ± 0.03	28.21	0.77 ± 0.25	70
Asclepias spp.*	<0.01	20.51	—	—
Asclepias ovalifolia	0.02 ± 0.01	2.56	0.03 ± 0.01	30
Asclepias viridula	0.02 ± 0.01	12.82	0.04 ± 0.03	30

Appendix C. Continued.

Species	Inhabited Transects		Formerly Inhabited Transects	
	Average Cover (%) ± SE	Frequency (%)	Average Cover (%) ± SE	Frequency (%)
Astragalus adsurgens	0.13 ± 0.08	10.26	1.58 ± 0.78	40
Astragalus agrestis	0.05 ± 0.03	15.39	<0.01	20
Astragalus canadensis	<0.01	2.56	0.07 ± 0.07	10
Astragalus crassicarpus	1.14 ± 0.25	64.10	0.21 ± 0.09	40
Astragalus flexuosus	0.02 ± 0.01	20.51	0.03 ± 0.03	10
Astragalus sp.	0.02 ± 0.01	15.38	0.08 ± 0.02	60
Avenula hookeri	0.04 ± 0.02	12.82	—	—
Bouteloua curtipendula	0.81 ± 0.34	33.33	0.32 ± 0.25	30
Bouteloua gracilis	0.07 ± 0.03	28.21	0.06 ± 0.05	20
Bromus inermis	1.40 ± 0.03	84.61	3.98 ± 1.20	90
Calystegia macounii	0.02 ± 0.02	2.56	0.01 ± 0.01	10
Calylophus serrulatus	0.02 ± 0.01	17.95	0.03 ± 0.01	30
Carex filifolia	0.10 ± 0.07	7.69	—	—
Carex inops	0.01 ± 0.01	2.56	—	—
Carex meadii	0.12 ± 0.09	17.95	—	—
Carex spp.**	0.23 ± 0.02	89.74	0.17 ± 0.05	70
Castilleja sessiliflora	0.03 ± 0.01	17.95	0.03 ± 0.02	20
Cerastium arvense	0.18 ± 0.03	61.54	0.10 ± 0.05	40
Chamaesyce sp.	<0.01	2.56	—	—

Appendix C. Continued.

Species	Inhabited Transects		Formerly Inhabited Transects	
	Average Cover (%) ± SE	Frequency (%)	Average Cover (%) ± SE	Frequency (%)
Chenopodium album	0.01 ± 0.01	2.56	—	—
Chenopodium sp.	<0.01	5.13	—	—
Cirsium arvense	—	—	0.01 ± 0.01	10
Cirsium flodmanii	0.15 ± 0.02	79.49	0.16 ± 0.07	70
Comandra umbellata	0.36 ± 0.05	92.31	0.68 ± 0.19	100
Convolvulus arvensis	<0.01	2.56	—	—
Conyza canadensis	0.01 ± 0.01	2.56	—	—
Dalea candida	0.01 ± <0.01	5.13	0.01 ± 0.01	10
Dalea purpurea	0.16 ± 0.02	76.92	0.24 ± 0.08	60
Delphinium carolinianum	0.02 ± 0.01	12.82	—	—
Dichanthelium leibergii	0.31 ± 0.10	48.72	0.49 ± 0.30	50
Dichanthelium oligosanthes	0.01 ± <0.01	7.69	0.01 ± 0.01	10
Dichanthelium wilcoxianum	0.13 ± 0.02	82.05	0.25 ± 0.10	90
Echinacea angustifolia	1.19 ± 0.21	94.87	0.97 ± 0.17	100
Elymus repens	0.09 ± 0.08	7.69	—	—
Elymus trachycaulus	0.04 ± 0.01	30.77	0.03 ± 0.02	20
Erigeron glabellus	<0.01	2.56	—	—
Erigeron strigosus	<0.01	5.13	—	—
Escobaria vivipara	0.02 ± 0.01	7.69	—	—

Appendix C. Continued.

	Inhabited Transects		Formerly Inhabited Transects	
Species	Average Cover (%) ± SE	Frequency (%)	Average Cover (%) ± SE	Frequency (%)
Euphorbia sp.	<0.01	5.13	—	—
Fragaria virginiana	<0.01	2.56	0.01 ± 0.01	10
Gaillardia aristata	0.02 ± 0.01	17.95	0.07 ± 0.04	30
Galium boreale	1.7 ± 0.42	82.05	3.85 ± 1.20	100
Gaura coccinea	0.04 ± 0.02	20.51	0.04 ± 0.03	30
Gentiana puberulenta	<0.01	2.56	—	—
Geum triflorum	0.02 ± 0.01	10.26	—	—
Glycyrrhiza lepidota	—	—	0.25 ± 0.25	10
Hedeoma hispida	0.03 ± 0.01	12.82	—	—
Heliopsis helianthoides	0.01 ± <0.01	7.69	—	—
Helianthus maximiliani	<0.01	5.13	—	—
Helianthus pauciflorus	1.33 ± 0.32	74.36	1.95 ± 0.50	80
Helianthus sp.	<0.01	2.56	—	—
Hesperostipa comata	0.77 ± 0.27	43.59	2.63 ± 1.10	60
Hesperostipa spartea	11.96 ± 1.32	94.87	5.47 ± 1.31	90
Heterotheca villosa	0.03 ± 0.02	10.26	0.13 ± 0.08	30
Heuchera richardsonii	0.03 ± 0.01	23.08	—	—
Hordeum jubatum	<0.01	5.13	—	—
Hypoxis hirsuta	<0.01	2.56	—	—
Koeleria macrantha	0.24 ± 0.05	79.49	0.32 ± 0.15	50

Appendix C. Continued.

Species	Inhabited Transects Average Cover (%) ± SE	Inhabited Transects Frequency (%)	Formerly Inhabited Transects Average Cover (%) ± SE	Formerly Inhabited Transects Frequency (%)
Lactuca tatarica	0.20 ± 0.05	69.23	0.01 ± 0.01	10
Lathyrus sp.	<0.01	2.56	—	—
Lathyrus venosus	0.22 ± 0.08	30.77	0.03 ± 0.01	30
Lepidium densiflorum	0.01 ± 0.01	2.56	—	—
Liatris punctata	0.31 ± 0.08	46.15	0.44 ± 0.20	60
Liatris spp.***	0.08 ± 0.04	25.64	0.01 ± 0.01	10
Lilium philadelphicum	<0.01	2.56	—	—
Linum rigidum	0.05 ± 0.01	35.90	0.01 ± 0.01	10
Lithospermum canescens	0.07 ± 0.02	43.59	0.20 ± 0.07	70
Lithospermum incisum	0.04 ± 0.02	20.51	0.01 ± 0.01	10
Lobelia spicata	—	—	0.02 ± 0.01	20
Lomatium spp.****	0.04 ± 0.02	15.38	0.01 ± 0.01	10
Lotus unifoliatus	<0.01	2.56	—	—
Lygodesmia juncea	0.03 ± 0.01	20.51	0.01 ± 0.01	10
Maianthemum stellatum	—	—	0.01 ± 0.01	10
Medicago lupulina	<0.01	2.56	0.01 ± 0.01	10
Medicago sativa	—	—	0.50 ± 0.33	20
Melilotus officinalis	0.29 ± 0.05	79.49	0.84 ± 0.32	70
Mirabilis nyctaginea	<0.01	2.56	—	—

Appendix C. Continued.

	Inhabited Transects		Formerly Inhabited Transects	
Species	Average Cover (%) ± SE	Frequency (%)	Average Cover (%) ± SE	Frequency (%)
Monarda fistulosa	—	—	0.38 ± 0.19	50
Nassella viridula	0.07 ± 0.02	33.33	0.28 ± 0.26	20
Oligoneuron album	0.01 ± 0.01	10.26	—	—
Oligoneuron rigidum	0.36 ± 0.14	48.72	0.68 ± 0.30	90
Onosmodium bejariense	—	—	0.03 ± 0.02	30
Oxalis stricta	0.04 ± 0.02	17.95	0.05 ± 0.05	10
Oxalis violacea	0.13 ± 0.05	48.72	0.04 ± 0.01	50
Oxytropis lambertii	0.04 ± 0.02	7.69	—	—
Packera plattensis	0.01 ± 0.00	7.69	0.03 ± 0.02	30
Panicum virgatum	0.06 ± 0.02	15.38	0.02 ± 0.01	20
Pascopyrum smithii	—	—	0.01 ± 0.01	10
Pediomelum argophyllum	1.10 ± 0.24	87.18	0.50 ± 0.12	90
Pedicularis canadensis	<0.01	2.56	—	—
Pediomelum esculentum	0.20 ± 0.04	66.67	0.16 ± 0.08	40
Penstemon gracilis	0.02 ± 0.01	23.08	—	—
Phleum pratense	0.34 ± 0.18	35.90	—	—
Physalis virginiana	0.08 ± 0.02	51.28	0.15 ± 0.03	90
Poa compressa	<0.01	2.56	—	—
Poa pratensis	1.51 ± 0.28	100.00	2.68 ± 1.20	100
Polygala alba	0.01 ± 0.01	10.26	—	—

Appendix C. Continued.

Species	Inhabited Transects		Formerly Inhabited Transects	
	Average Cover (%) ± SE	Frequency (%)	Average Cover (%) ± SE	Frequency (%)
Polygonum convolvulus	<0.01	5.13	—	—
Polygala spp.*****	0.02 ± 0.01	5.13	—	—
Polygala verticillata	0.05 ± 0.01	43.59	—	—
Potentilla arguta	0.02 ± 0.01	10.26	—	—
Potentilla pensylvanica	0.01 ± 0.01	10.26	0.03 ± 0.02	20
Prunus americana	0.02 ± 0.01	2.56	—	—
Pulsatilla patens	0.59 ± 0.14	69.23	0.24 ± 0.11	70
Ratibida columnifera	0.04 ± 0.01	28.21	0.03 ± 0.02	20
Rosa arkansana	0.60 ± 0.22	56.41	0.92 ± 0.30	70
Rudbeckia hirta	—	—	—	—
Schizachyrium scoparium	13.73 ± 2.06	97.44	9.59 ± 2.74	100
Scolochloa festucacea	—	—	0.01 ± 0.01	10
Scutellaria parvula	<0.01	5.13	0.03 ± 0.01	30
Silene antirrhina	0.01 ± 0.00	5.13	—	—
Sisyrinchium campestre	0.01 ± 0.01	2.56	—	—
Sisyrinchium montanum	<0.01	2.56	0.02 ± 0.01	20
Sisyrinchium spp.******	0.03 ± 0.01	12.82	0.01 ± 0.01	10
Solidago canadensis	0.02 ± 0.02	7.69	1.48 ± 1.14	50
Solidago missouriensis	0.16 ± 0.03	76.92	0.16 ± 0.07	60
Sorghastrum nutans	0.02 ± 0.01	7.69	—	—

Appendix C. Continued.

Species	Inhabited Transects Average Cover (%) ± SE	Inhabited Transects Frequency (%)	Formerly Inhabited Transects Average Cover (%) ± SE	Formerly Inhabited Transects Frequency (%)
Sporobolus compositus	—	—	0.08 ± 0.05	40
Sporobolus cryptandrus	0.01 ± <0.01	7.69	0.02 ± 0.01	20
Sporobolus heterolepis	0.60 ± 0.24	38.46	0.27 ± 0.26	20
Stachys palustris	0.01 ± 0.01	2.56	0.01 ± 0.01	10
Symphoricarpos occidentalis	0.63 ± 0.15	56.41	1.49 ± 0.73	70
Symphyotrichum ericoides	0.22 ± 0.04	82.05	0.41 ± 0.11	100
Symphyotrichum oblongifolium	0.01 ± 0.01	10.26	0.12 ± 0.12	10
Symphyotrichum sericeum	0.23 ± 0.05	61.54	0.63 ± 0.29	60
Taraxacum officinale	0.42 ± 0.09	84.62	0.10 ± 0.03	60
Thalictrum venulosum	0.20 ± 0.05	43.59	0.02 ± 0.01	20
Tragopogon dubius	0.08 ± 0.02	53.85	0.02 ± 0.02	10
Trifolium pratense	0.02 ± 0.01	5.13	—	—
Trifolium repens	<0.01	2.56	—	—
Verbena stricta	<0.01	2.56	—	—
Vicia americana	0.03 ± 0.03	5.13	—	—
Viola pedatifida	0.54 ± 0.09	84.62	0.28 ± 0.08	90
Zigadenus elegans	0.08 ± 0.04	28.21	0.02 ± 0.02	10
Zizia aptera	0.17 ± 0.06	43.59	—	—

*Includes species *Asclepias speciosa* and/or *Asclepias syriaca*

Appendix C. Continued.

**Includes more than three species that could be identified only to the genus *Carex*
***Includes species *Liatris aspera* and/or *Liatris ligulistylis*
****Includes species *Lomatium foeniculaceum* and/or *Lomatium orientale*
*****Includes species *Polygala verticillata* and/or *Polygala alba*
******Includes species *Sisyrinchium montanum* and/or *Sisyrinchium campestre*

Appendix D. Average Density of Flowering Stems of Species of Inhabited and Formerly Inhabited Transects

	Inhabited Transects		Formerly Inhabited Transects	
Species	Mean Density (no./m^2) ± SE	Frequency (%)	Mean Density (no./m^2) ± SE	Frequency (%)
Achillea millefolium	0.05 ± 0.01	79.49	0.11 ± 0.08	50
Agoseris glauca	0.03 ± 0.01	41.03	—	—
Amorpha canescens	<0.01	2.56	—	—
Anemone canadensis	0.01 ± <0.01	12.82	<0.01	10
Anemone cylindrica	0.10 ± 0.02	71.79	0.04 ± 0.03	30
Arabis hirsuta	<0.01	17.95	<0.01	20
Asclepias viridula	<0.01	5.13	—	—
Astragalus adsurgens	0.18 ± 0.09	41.03	1.86 ± 0.93	40
Astragalus agrestis	—	—	<0.01	10
Calylophus serrulatus	0.02 ± 0.01	48.72	0.08 ± 0.03	90
Cerastium arvense	<0.01	5.13	<0.01	20
Dalea candida	<0.01	2.56	—	—
Delphinium carolinianum	0.02 ± <0.01	53.85	<0.01	20
Echinacea angustifolia	0.42 ± 0.09	94.87	0.36 ± 0.10	100
Erigeron strigosus	0.03 ± 0.01	82.05	0.01 ± <0.01	70
Erysimum incisum	<0.01	2.56	<0.01	20
Gaillardia aristata	<0.01	10.26	0.01 ± 0.01	30
Galium boreale	0.03 ± 0.02	41.03	1.52 ± 1.03	80
Gaura coccinea	<0.01	12.82	0.02 ± 0.02	20
Glycyrrhiza lepidota	—	—	0.01 ± <0.01	20

Appendix D. Continued.

Species	Inhabited Transects Mean Density (no./m^2) ± SE	Inhabited Transects Frequency (%)	Formerly Inhabited Transects Mean Density (no./m^2) ± SE	Formerly Inhabited Transects Frequency (%)
Heliopsis helianthoides	<0.01	7.69	<0.01	10
Heterotheca villosa	0.0077 ± <0.01	23.08	0.03 ± 0.03	20
Lathyrus venosus	—	—	<0.01	10
Lilium philadelphicum	<0.01	2.56	—	—
Lithospermum canescens	<0.01	5.13	<0.01	40
Linum rigidum	0.03 ± 0.01	48.72	0.02 ± 0.01	40
Lobelia spicata	0.01 ± <0.01	23.08	0.01 ± 0.01	20
Medicago lupulina	0.01 ± <0.01	12.82	0.20 ± 0.14	30
Medicago sativa	<0.01	5.13	0.23 ± 0.14	40
Melilotus officinalis	0.31 ±0.15	53.85	1.79 ± 0.91	80
Onosmodium bejariense	<0.01	2.56	0.02 ± 0.02	10
Oxytropis lambertii	<0.01	5.13	0.01 ± 0.01	10
Pediomelum argophyllum	0.15 ± 0.04	66.67	0.13 ± 0.05	80
Penstemon gracilis	0.02 ± <0.01	43.59	0.01 ± <0.01	30
Polygala alba	0.06 ± 0.04	7.69	—	—
Polygala verticillata	<0.01	5.13	<0.01	10
Potentilla arguta	<0.01	10.26	—	—
Potentilla pensylvanica	<0.01	10.26	0.01 ± <0.01	50
Ratibida columnifera	<0.01	7.69	—	—
Rosa arkansana	<0.01	15.38	0.01 ± 0.01	20

Appendix D. Continued.

	Inhabited Transects		Formerly Inhabited Transects	
Species	Mean Density (no./m^2) ± SE	Frequency (%)	Mean Density (no./m^2) ± SE	Frequency (%)
Sisyrinchium montanum	—	—	<0.01	20
Symphoricarpos occidentalis	<0.01	2.56	0.08 ± 0.08	20
Thalictrum venulosum	0.01 ± 0.01	15.38	<0.01	20
Tragopogon dubius	0.01 ± 0.01	20.51	0.01 ± 0.01	20
Trifolium pratense	<0.01	5.13	—	—
Zigadenus elegans	0.01 ± 0.01	12.82	0.07 ± 0.07	20
Zizia aptera	0.01 ± 0.01	10.26	—	—